Protection in Space: A Self-Defense Acquisition Priority for U.S. Satellites

A Monograph
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AY 2008

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
30-04-2008	SAMS Monograph	JUL 2007 – MAY 2008

4. TITLE AND SUBTITLE Protection in Space: A Self-Defense Acquisition Priority for U.S. Satellites	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) MAJOR Kurt M. Schendzielos (U.S. Air Force)	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Advanced Military Studies Program 250 Gibbon Avenue Fort Leavenworth, KS 66027-2134	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Command and General Staff College 1 Reynolds Avenue Fort Leavenworth, KS 66027	**10. SPONSOR/MONITOR'S ACRONYM(S)** CGSC
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
America is critically reliant upon space exploitation, ranging from military capabilities to civilian applications. Recent developments in anti-satellite technologies signal a dangerous threat to U.S. space dominance. Zero-warning threats such as ground-based lasers or direct-ascent kinetic-kill vehicles present the biggest challenge for which there is little or no defense. Until recently, the U.S. had been reasonably free from disablement. Unfortunately, many adversary nations acquired anti-satellite technologies and proliferated them; threatening permanent disablement of almost any American satellite. This monograph surveys available unclassified literature to assess current and emerging threats to U.S. satellites and evaluates open source defenses available, ranging from policy mechanisms to physical defenses. The monograph reviews various promising technologies in development that could be obtained to defend U.S. satellites in the timeframe commensurate with the proliferation and risk of anti-satellite threats. An advocacy suggesting that increased national resources and efforts be devoted to protecting Low-Earth Orbiting satellites from zero-warning attacks is proposed.

15. SUBJECT TERMS
Satellite Defense, Satellite Self-Defense, Satellite Protection, Satellite Protectionm, Counterspace, Defensive Counterspace, Offensive Counterspace, Active DCS, Passive DCS, Anti-Satellite, ASAT, Suppression of Adversary Counterspace Capability

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Stefan J. Banach, COL, US Army
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	UU	72	**19b. TELEPHONE NUMBER** *(include area code)* 913-758-3302

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

Major Kurt M. Schendzielos

Title of Monograph: Protection in Space: A Self-Defense Acquisition Priority for U.S. Satellites

This monograph was defended by the degree candidate on 23 April 2008 and approved by the monograph director and reader named below.

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Abstract

PROTECTION IN SPACE: A SELF-DEFENSE ACQUISITION PRIORITY FOR U.S. SATELLITES by MAJOR Kurt M. Schendzielos, USAF, 72 pages.

America is critically reliant upon space exploitation for a wide variety of activities. These range from strictly military capabilities such as intelligence gathering and secure communications to civilian financial transaction timing and remote Earth sensing for environmental analysis. Recent developments in anti-satellite technologies signal a dangerous threat to U.S. space dominance. Specifically, zero-warning threats such as ground-based lasers or direct-ascent kinetic-kill vehicles present the biggest challenge for which there is little or no defense.

Until recently, the U.S. had been reasonably secure that its satellites were free from disablement. Unfortunately, many adversary nations acquired anti-satellite technologies and proliferated them; threatening permanent disablement of almost any American satellite.

This monograph surveys available unclassified literature to assess current and emerging threats to U.S. satellites and evaluates open source defenses available, ranging from policy mechanisms to physical defenses. The level of protection is wanting and the monograph reviews various promising technologies in development currently that could be obtained to defend U.S. satellites in the timeframe commensurate with the proliferation and risk of anti-satellite threats. An advocacy suggesting that increased national resources and efforts be devoted to protecting Low-Earth Orbiting satellites from zero-warning attacks is proposed.

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Introduction

On a sunny winter day, 13 December 2001, President George Bush announced he had provided the Russian government a formal notice of abrogation of the bilateral *Anti-Ballistic Missile Treaty of 1972* paving the way for the post-September 11th U.S. to pursue unhindered ballistic missile self-defense research and development six months later.[1] As an added side benefit, the U.S. eliminated one of the only diplomatic restrictions to U.S. anti-satellite (ASAT) development. It was now able to explore many of the recommendations of the Commission to Assess United States National Security Space Management and Organization (CAUSNSSMO), specifically to "Develop and deploy the means to deter and defend against hostile acts directed at U.S. space assets and against the users of space hostile to U.S. interests."[2] World reaction, specifically the Russians and Chinese, expressed disappointment with the decision; however both countries released statements reiterating the fact that they did not perceive an increased threat to their respective national securities.

Five years later, the White House published the newly updated *National Space Policy* (*NSP*). Compared to previous *NSP*s the 2006 *NSP* was largely identified as having a decidedly aggressive tone.[3] Many critics cited examples such as the principle that,

> the United States will: preserve its rights, capabilities, and freedom of action in space; dissuade or deter others from either impeding those rights or developing capabilities intended to do so; take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests.[4]

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[1] Manuel Perez-Rivas, "US Quits ABM Treaty," CNN.Com Inside Politics, 14 December 2001, http://archives.cnn.com/2001/ALLPOLITICS/12/13/rec.bush.abm/ (accessed 12 February 2008).

[2] Commission to Assess United States National Security Space Management and Organization (CAUSNSSMO), *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington, DC: Congressional Press, 2001), xv.

[3] Peter Brookes, "Militarizing Space," The Heritage Foundation, 7 June 2005, http://www.heritage.org/Press/Commentary/ed060705a.cfm (accessed 12 February 2008).

[4] United States President, *National Security Presidential Directive NSPD-48: National Space Policy* (Washington, DC: Government Printing Office. 2006), 1.

The U.S. sent a clear message: it is clearly dependent upon space and will challenge any disruption to that advantage. A large motivating factor for the U.S. declaration was aggressive counterspace research and development taking place both in China and Russia.[5] China, specifically, is posturing itself to be in a position to challenge U.S. space dominance, if necessary.[6] In dramatic fashion, China demonstrated how far it had come with a successful kinetic kill of one of its own decommissioned weather satellites in January 2007.[7]

China is only the latest country to field anti-satellite technology, following in the footsteps of established space powers like the U.S. and the former Soviet Union. Other countries including the European Union, India, Iran, Israel, Japan, and North Korea are in various stages of suspected research and development of space control and counterspace technologies.[8] As many as thirty countries have the capability to affect a satellite from a ground based laser.[9] It is not unreasonable to suspect that potential adversaries of the U.S., including non-state and terrorist organizations, will seek to partner with space power nations or will directly acquire proliferated counterspace capability in order to exploit American reliance on space. Future conflicts will only further obviate the need to protect American satellites from interference.

All aspects of American power are critically dependent upon military and civilian space exploitation. Temporary anti-satellite denial techniques like dazzling are nuisances but can be readily dealt with, not requiring immediate replacement. The U.S. space acquisition system and

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[5] The Chinese at the time were testing kinetic kill and directed energy means to produce a functional kill or complete kill of satellite vehicles. Additional research and testing was being spent in the fields of blinding, dazzling and denial of signals across the radio frequency spectrum, including communications and global positioning system signals.

[6] Theresa Hitchens, "Monsters and Shadows: Left Unchecked, American Fears Regarding Threats to Space Assets Will Drive Weaponization," *Disarmament Forum*, no. 1 (2003): 25.

[7] Eric Hagt, "China's ASAT Test: Strategic Response," *China Security* 3, no. 1 (Winter 2007): 31.

[8] Clayton K. S. Chun, *Shooting Down a Star: Program 437, the U.S. Nuclear ASAT System and Present Day Copycat Killers* (Maxwell AFB, AL: USAF Air University. April 2000), 36; Simon Collard-Wexler et al., *Space Security Index 2004* (Waterloo, Ontario: Space Security Index, June 2005), 37-38.

[9] Kimberly M. Schlie, “Developing and Deploying Laser Weaponry in Space: Is It Legal?” *DePaul International Law Journal* 4 (Winter 2000): 24.

lift capacity is not currently able to respond rapidly and responsively to immediate replacement of any single satellite, much less repopulation of a constellation. Permanently crippling or destroying satellites severely hampers the U.S. for conceivably long durations and levels the playing field for a competing adversary.

Because Low Earth Orbiting (LEO) satellites are vulnerable to attack with little to no warning, contemporary methods of space control including counterspace kinetic strikes are useless unless ample unambiguous warning of a pending attack exists or the U.S. takes preemptive measures to disable the offending system.[10] Current satellite protective methods are stop-gap measures that may have little efficacy against emerging threats. There is currently no self-defense against permanent satellite disablement (for example: Kinetic ASAT, high energy laser.) Today's direct ascent and ground-based laser destructive ASAT technologies currently only threaten the LEO regime; various systems such as the semi-synchronous Global Positioning System (GPS) and geosynchronous Defense Satellite Communication System (DSCS) satellites are relatively safe from no-notice permanent disablement.[11] Newer technologies including co-orbital ASATs certainly can threaten any man-made satellite, but there is a greater chance of warning of such an attack, providing the U.S. time to employ defensive actions. Unfortunately, most remote sensing, weather, reconnaissance, surveillance and some communications satellites reside in the LEO regime and are therefore subject to permanent disablement. It can take years to build and launch a replacement satellite and potentially decades to re-populate constellations of

[10] The Inter-Agency Space Debris Coordination Committee, an international organization to which the National Air and Space Administration is a member, defines LEO as extending from the surface of the Earth up to 2000km. The 2000km (Z) distance is mostly agreed upon. Depending upon the source, the lower altitude limit varies from 800km down to the surface of the Earth. Part of the confusion comes from a lack of definition or agreement for what makes an object a spacecraft vice a high flying aircraft.

[11] Growing research and development involves micro- and pico-satellites which could be placed in a semi- or geosynchronous orbit and utilized as co-orbital ASATs. The timeline associated with such an attack is much longer than a direct ascent LEO attack providing a better chance of warning and more time to command defensive measures for a targeted semi- or geo- satellite. The limited warning and inability of a timely response makes the LEO region so dangerous today.

satellites. Certain orbits may be unavailable because of debris fields from destructive attacks; further hindering constellation replenishment. Loss of U.S. space assets would severely constrain American dominance in expeditionary conflict and, depending upon the satellites disabled, could severely cripple the American and possibly even world economy.

Thesis

The U.S. should re-prioritize near-term (next ten years) research, development, acquisition, and fielding of LEO satellite self-protection measures to mitigate vulnerability to little to no-warning destructive ASAT attack. The cost of increased research and development will be high and will likely threaten terrestrial military program improvement, but will outweigh the vulnerability that is necessarily incurred by the current lack of satellite defense development, especially in the context of national space exploitation reliance. The acquisition timeline to field a satellite defense capability necessitates that robust research, development and fielding occur now to keep pace against possible peer-competitor ASAT space powers during the next ten to fifteen years.

Additional questions must be addressed in order to determine if the U.S. should more aggressively develop LEO satellite self-defense technologies during the next decade. First, what are the contemporary and next decade destructive no-warning ASAT technologies threatening U.S. satellites? Second, what counterspace mitigation efforts are already being used and developed for the near-term and what is their effectiveness? Lastly, what are the relative merits and demerits of more aggressive development and fielding of LEO satellite self-defense capability?

Terms

Space Control is defined within joint doctrine as:

> Combat, combat support, and combat service support operations to ensure freedom of action in space for the United States and its allies and, when directed, deny an adversary

> freedom of action in space. The space control mission area includes: surveillance of space; protection of U.S. and friendly space systems; prevention of an adversary's ability to use space systems and services for purposes hostile to U.S. national security interests; negation of space systems and services used for purposes hostile to U.S. national security interests; and directly supporting battle management, command, control, communications, and intelligence.[12]

Counterspace is not defined in Joint terminology. The U.S. Air Force (USAF), as a lead agency for space doctrine thought, aligns space control with other mission areas such as counterair, and counterland through the term counterspace. Therefore, USAF doctrine defines counterspace as "Those offensive and defensive operations conducted by air, land, sea, space, special operations, and information forces with the objective of gaining and maintaining control of activities conducted in or through the space environment."[13] The USAF further breaks the counterspace mission into offensive and defensive components.

Offensive counterspace (OCS) is defined as "Operations to preclude an adversary from exploiting space to their advantage."[14] USAF doctrine categorizes OCS into five desired effects, mostly related to the level of damage achieved. These five desired effects in ascending order of intensity and irreversibility are: deception, disruption, denial, degradation and destruction. These terms are defined in USAF doctrine:

> - Deception employs manipulation, distortion, or falsification of information to induce adversaries to react in a manner contrary to their interests.
>
> - Disruption is the temporary impairment of some or all of a space system's capability to produce effects, usually without physical damage.
>
> - Denial is the temporary elimination of some or all of a space system's capability to produce effects, usually without physical damage.
>
> - Degradation is the permanent impairment of some or all of a space system's capability to produce results, usually with physical damage.

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[12] Department of Defense, *Joint Publication (JP) 1-02, Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: Government Printing Office, 12 October 2007), 499.

[13] Department of the Air Force, *Air Force Doctrine Document (AFDD) 2-2.1 Counterspace Operations* (Washington D.C.: Government Printing Office, 2 August 2004), 51.

[14] Ibid., 53.

- Destruction is the permanent elimination of all of a space system's capabilities to produce effects, usually with physical damage.[15]

Defensive counterspace (DCS) is defined as "Operations to preserve US/friendly ability to exploit space to its advantage via active and passive actions to protect friendly space-related capabilities from adversary attack or interference."[16] USAF doctrine further breaks DCS into three categories: deterrence, defense and recovery. Of those categories, defense is most written about, and is further broken down into subcategories of: attack detection and characterization, passive measures and active measures. Attack detection and characterization contains: detection, characterization, impact assessment and location.[17] These measures are the first step to effective real-time satellite protection and it is a current emphasis for space protection research at the Air Force Research Laboratory (AFRL).

Passive measures include: camouflage, concealment, and deception; system hardening and dispersal of space systems.[18] These methods are employed today with various facets of a space network from satellite ground stations to downlink nodes. Mostly, however, these measures are focused upon to the ground architecture. Very little has been done to conceal a satellite in space, and dispersal is not currently a feasible option, mostly due to a cost-benefit analysis comparing previous adversary space capabilities and UN space treaty restrictions.[19]

Active measures include: maneuver and mobility, system configuration changes and suppression of adversary counterspace capabilities (SACC).[20] As with passive measures, most of these methods are applied in a robust manner to the terrestrial-based portion of the space

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[15] Ibid., 31.

[16] Ibid., 51.

[17] Ibid., 26-27.

[18] Ibid., 26.

[19] In accordance with *the United Nations Convention on the Registration of Objects Launched Into Outer Space*, it would be illegal to completely hide a satellite. General orbital parameters and function of the satellite is reported to the UN for every man-made object orbiting Earth. How this is accomplished can be loosely interpreted, however, making a satellite completely disappear has serious legal implications.

[20] Department of the Air Force, *Air Force Doctrine Document (AFDD) 2-2.1*, 27.

architecture. Active satellite defense measures are more the purview of concept briefs and thought pieces to date. It is, however, an emphasis item for space protection advocates.

Limits and Delimits

For the purpose of discussion, as well as to ensure the widest possible dissemination, the debate contained in this paper will remain unclassified. While the details of research and development of space protection technologies reside at classified levels, generic and broad descriptions of capabilities usually exist in the unclassified realm. Military doctrine (specifically USAF doctrine) concerning satellite defense extols the virtues of demonstrating a capability and willingness to counter enemy counterspace efforts in order to deter and prevent future attacks.[21] There is little motivation to completely obfuscate satellite protection measures. It is reasonable to infer that what data is accessible at the unclassified level is sufficient to serve as a basis for the discussion at hand.

This discussion will also limit itself to the debate concerning no-notice immediate satellite protection. The emerging capabilities of counterspace nations against low and medium earth orbiting satellites renders current U.S. OCS measures ineffective. Responding to a ground-based laser by shooting a sub-sonic cruise missile from 800 miles away is not timely enough to protect the targeted satellite. That sort of response only works in a preemptive role or as a means of saving other satellites after having already taken losses. It also does not serve to protect a satellite from a kinetic kill vehicle launched from the ground or employed from space.

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[21] Ibid., 29.

Chapter 1 – The Imperative of Space

American Reliance on Space Capability

Modern life is critically dependent upon civil and military exploitation of space.[22] Instantaneous global communications are routine. The world relies upon the GPS constellation for international and domestic travel and for the timing of global financial transactions. Farmers, travelers, soldiers, and scientists rely heavily upon space imagery and sensors to predict weather and detect climate patterns. Modern militaries utilize space technologies for intelligence gathering, warning, communications, positioning and attack precision. There are vast arrays of uses that are taken for granted concerning the GPS constellation alone.[23]

America, in particular, is inextricably reliant upon space capabilities in order to maintain its dominance as a world superpower. CAUSNSSMO, an organization appointed by Congress with the charter of examining space activities in support of national security, concluded that "the security and well being of the United States, its allies and friends depends on the nation's ability to operate in space."[24] USAF Colonel David Ziegler, commander of the 460th Space Wing, which is charged with global surveillance and worldwide missile warning, observed:

> The United States is a space faring nation—it operates some 200 military and civilian satellites with a combined value of $100 billion. As impressive as these statistics appear, they do not reflect the additional billions of dollars and millions of American lives influenced every day by space communications, navigation, weather, environmental, and national security satellites. Space is big business and is inseparable from U.S. economic

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[22] Steven Lambakis, "Missile Defense From Space," *Policy Review*, no. 141 (February and March 2007), http://www.hoover.org/publications/policyreview/5516446.html (accessed 12 February 2008)..

[23] The CAUSNSSMO further identified how reliant the world in general is upon the GPS timing signal alone. The Commission wrote in its 2001 report that, "Loss of GPS timing could disable police, fire and ambulance communications around the world; disrupt the global banking and financial system, which depends on GPS timing to keep worldwide financial centers connected; and interrupt the operation of electric power distribution systems." CAUSNSSMO, 23.

[24] CAUSNSSMO, vii.

> strength. It attracts international attention and therefore diplomatic power. It is absolutely crucial to military operations.[25]

The Department of State International Security Advisory Board echoed the concern about threats to U.S. satellite dominance when it reported: "Many of our space-based assets serve both civilian and military users. Their destruction, or even the threat of their destruction, would have devastating economic and military implications. Threats, disruption, or damage to commercial satellite systems would wreak havoc on the U.S. and global economy."[26] Modern trade and commerce, in addition to military capability are no longer heavily but have become critically reliant upon utilization of space assets.

Space exploitation is what allows America to gain and maintain control of "the commons," areas identified by MIT political science professor Barry Posen that belong to no one but are shared by state and non-state actors. The commons include sea and space and certain portions of airspace. Posen explains,

> Command of the commons is the key military enabler of the U.S. global power position. It allows the United States to exploit more fully other sources of power, including its own economic and military might as well as the economic and military might of its allies. Command of the commons also helps the United States to weaken its adversaries, by restricting their access to economic, military, and political assistance.[27]

Without the ability to operate with commanding dominance in these arenas, America's expeditionary efforts would be hamstrung resulting in limited effectiveness and could lead to the loss of all expeditionary capability most likely resulting in a very insular, if not isolationist, withdrawal to American dominated territories and major centers of power. Effectively, the U.S.

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[25] David W. Ziegler, "Safe Havens: Military Strategy and Space Sanctuary Thought" (School for Advanced Air and Space Studies Thesis, Maxwell AFB, AL: Air University, June 1997), 7.

[26] United States State Department, *Study on Space Policy: Report of the International Security Advisory Board* (Washington, D.C.: United States State Department, 27 April 2007), 4.

[27] Barry R. Posen, "Command of the Commons: The Military Foundation of U.S. Hegemony," *International Security* 28, 1 (Summer 2003): 8-9.

would cease to be a superpower if it did not have the ability to project power enabled by commanding the commons.

The consequences of losing space dominance cannot be underestimated for U.S. military forces. Retired General Barry McCaffrey remarked in no uncertain terms about the need for dominance in the space arena after a visit to Nellis AFB. “Our global communications, ISR, and missile defense capabilities cannot operate without secure, robust, and modernized space platforms. We will drop back to WWII era capabilities if we suddenly lose our space advantage. Space is an under-resourced and inadequately defended vital U.S. technical capability.”[28] U.S. satellites are already under capitalized, therefore replacing them is problematic should an adversary begin to permanently disable them. McCaffrey’s remarks also implies a desire to avoid redundancy of space capabilities while balancing the need for more secure and modernized space platforms, based upon the absolute reliance of the military upon space capability. Clearly, there is a lot at stake for America if it does not enjoy space dominance.

War Expanded Into the Space Arena

The successful launch of Sputnik (4 October 1957) heralded a new era for mankind. Deeply embroiled in a cold war, Americans viewed the launch initially with awe and trepidation; concern immediately followed.[29] If the Russians could orbit a radio, what would prevent them from orbiting a nuclear warhead? From the very first step to slip the surly bonds and explore the boundaries surrounding Earth, space flight has been inexorably tied with the all-too-human

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[28] Barry R. McCaffrey, “After Action Report—General Barry R McCaffrey USA (Ret) Visit Nellis and Scott AFB 14-17 August 2007,” 15 October 2007 http://www.maxwell.af.mil/au/aunews/archive/0220/Articles/Air%20Force%20AAR%20-%20101207.pdf (accessed 12 February 2008).

[29] John Noble Wilford, “With Fear and Wonder in Its Wake, Sputnik Lifted Us Into the Future,” *New York Times*, 25 September 2007 http://www.nytimes.com/2007/09/25/science/space/25sput.html?ref=science, (accessed 12 February 2008).

conduct of war.[30] Immediate steps were taken to orbit reconnaissance platforms, then communications platforms. Commensurate with these efforts was the inevitable speculation of orbiting weapons, especially nuclear ones.

With the specter of a space war looming, a series of debates and recommendations were proposed inside the UN, focused specifically within the Committee on the Peaceful Uses of Outer Space (COPUOS).[31] The work of COPUOS resulted in five major space treaties.[32] None of these treaties explicitly prohibit the use of weapons in space (save weapons of mass destruction which are banned by the Outer Space Treaty,) weapons used against space objects or the militarization of space. It is technically a legal conduct of war to destroy another country's satellite, both from the ground or using a weapon orbiting the Earth.[33] Weapons could be orbited in a passive role and assuming the weapon was not involved in an aggressive act, it would be equivalent to a carrier battle group navigating the world's oceans, legally free to do so unhindered. No treaties or other bodies of international law prevent the expansion of war into space despite the generic ideal prefacing all five space treaties that space be used for peaceful purposes.[34]

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[30] Louis Ridenour, "Significance of a satellite vehicle", *Preliminary Design of an Experimental World-Circling Spaceship*, Douglas Aircraft Company Inc., Santa Monica Plant, Engineering Division, 1946.

[31] Nandasiri Jasentuliyana, *International Space Law and the United Nations*, (Springer: Kluwer Law International July 1999), 23.

[32] These five treaties include: *The 1966 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* ("Outer Space Treaty"), *The 1967 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space* ("The Rescue Agreement"), *The 1971 Convention on International Liability for Damage Caused by Space Objects* ("The Liability Convention"), *The 1974 Convention on Registration of Objects Launched into Outer Space* ("The Registration Convention"), and *The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* ("The Moon Agreement"). Of these the U.S. is a signatory to all except *The Moon Agreement*.

[33] Peter Jankowitch, "Legal Aspects of Military Space Activities." Ed. Nandasiri Jasentuliyana. foreword by Manfred Lachs. *A Publication of the International Institute of Space Law. Space law: Development and scope*, (Westport, CT, London: Praeger Press. 1992) 142-148.

[34] *The Moon Agreement* does prohibit the stationing of any weapons or military forces upon the moon, however the applicability of such a move today is dubious and the U.S. is not party to the

How a nation interprets “peaceful purposes” varies. The U.S. interpretation is that peaceful use does not implicitly sanction orbiting weapons; however, intelligence gathering satellites to determine targets and discern enemy intentions, communications satellites to coordinate operations and provide commands, GPS to guide weapons and forces, and missile warning satellites to prevent counter-attack are allowed.[35] The U.S. further reserves the right in the future to protect and defend itself and does not rule out ASAT weapons to accomplish that prerogative, a move made easier with the abrogation of the 1972 *Treaty on the Limitation of Anti-Ballistic Missile Systems*.[36] Space has already been militarized and therefore is being used to conduct war. Modern expeditionary and precision warfare cannot be conducted without space assets. What logically follows is that the full gambit of warfare will inevitably progress into space in the same way it did for other mediums like water and air.[37]

Nature of the U.S. Space Adversary

Because the technology required to effectively prosecute a large-scale destructive war in space is very expensive and highly technical, it is currently limited to only a handful of dedicated space faring countries. This does not protect American space capacity from even the most

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Agreement, though it does serve as a basis of customary international law and would be a hurdle to American interests to weaponize the moon.

[35] Allan Rosas, “The Militarization of Space and International Law.” *Journal of Peace Research* 20, no. 4: (1983): 3. The 2006 National Space Policy also states, “The United States is committed to the exploration and use of outer space by all nations for peaceful purposes, and for the benefit of all humanity. Consistent with this principle, ‘peaceful purposes’ allow U.S. defense and intelligence-related activities in pursuit of national interests” Major William Spacy concluded in his 1998 SAASS thesis: “The vagueness with which ‘peaceful purposes’ is defined has prompted considerable discussion of its meaning. Interpretation ranges from banning any type of weapon whatsoever, to permitting purely defensive weapons to be deployed. None of the interpretations would permit the deployment of offensive weapons in space.”; William Spacy II, “Does the United States need space-based weapons?” School of Advanced Air and Space Studies Thesis (Air University, Maxwell AFB, AL, 1998), 89.

[36] *NSPD-48*, 1-2. The CASUNSSMO 2001 Report, chaired by Donald Rumsfeld, also states: “The U.S. will require means of negating satellite threats, whether temporary and reversible or physically destructive.” CASUNNSMO, 29.

[37] Thomas D. Bell, *Weaponization of Space: Understanding Strategic and Technologic Inevitabilities*, Occasional Paper no. 6, (Center for Strategy and Technology, Air War College, Air University Press, Maxwell AFB, AL. January 1999), 3.

modest of attempts to disrupt or degrade space capability by any number of organizations. It is surprisingly easy to degrade LEO remote sensors. Denial and disruption of LEO sensors is even more widespread and easier to achieve from a technical point of view. Disruption of a signal from space occurs often and simply requires commercially available equipment. Denial and disruption of LEO sensors is the major concern today with destruction being a somewhat close second. However, that can shift quickly with rapid advances in the space weapons arena.

For example, USAF scientists discovered during a 1997 test of an ASAT laser that while the weapon laser did not fire (due to a technical malfunction,) the small wattage tracking laser did inflict minor non-permanent damage (dazzling) to the satellite's sensors.[38] As Union of Concerned Scientists author Laura Grego explains, "That a commercially available laser and a 1.5 m mirror could be an effective ASAT highlighted a U.S. vulnerability that had not been fully appreciated."[39] The results of the test caused quite a stir among other space-faring nations and the Russians immediately asked for an investigation into whether it constituted a breach of anti-ASAT testing agreements the U.S. held with Russia at the time.

To date, thankfully, the ability to dazzle a satellite, while relatively simple given the resource pool of a nation-state like China, is generally outside the reach of terrorist organizations, such as Al Qaeda, unless aided with reconnaissance and tracking data from one of the capable space faring nations.[40] Unfortunately, obtaining reliable tracking data on most satellites is becoming easier to accomplish, especially via the internet and shared amateur observations, but it has not yet reached the level of precision necessary for a non-government actor (NGA) to engage

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[38] Laura Grego, "Space Weapon Basics, A History of Anti-Satellite Weapons Programs," Union of Concerned Scientists, 2003, http://www.ucsusa.org/global_security/space_weapons/a-history-of-asat-programs.html (accessed 12 February 2008).

[39] Ibid.

[40] Tom Wilson, *Threat Annex to Report of the Commission to Assess United States National Security Space Management and Organization*. Threats to United States Space Capabilities, Prepared for the Commission to Assess United States National Security Space Management and Organization, (Washington, DC: Congressional Press, 2001), 7.

a space target without significant assistance.[41] Upon obtaining adequately precise tracking information, an NGA could theoretically obtain a laser capable of dazzling, although movement of such equipment and materials would most likely be detected by international intelligence organizations. The NGA would still have to appropriately stabilize the weapon, point it at the correct location, and precess it at the correct rate in order to achieve tangible results.[42]

The ability to permanently disable an orbiting platform's sensors, or the vehicle itself, requires massive resources and infrastructure that currently, and in the foreseeable future, only exists at a nation-state level. Theresa Hitchins of the UN Institute of Disarmament Research (UNIDR) explains, "There are fundamental technical obstacles to the development of kinetic kill weapons and lasers both for use against targets in space and terrestrial targets, and the costs associated with launch and maintaining systems on-orbit are staggering."[43] The only way a guerilla force, NGA or third-world nation-state would be able to achieve a level of degradation of U.S. space superiority is if it were aided by an adversary space faring nation, such as Russia, China, North Korea, Iran, Libya, or India.[44] Even then, the 2007 Defense Intelligence Agency (DIA) *Report on Current and Projected National Security Threats* argues that because of the high costs involved only China is projected to domestically produce a destructive ASAT system.[45] The 2007 DIA report concluded that within the next five years, "Other states and non-state entities are pursuing more limited and asymmetric approaches that do not require excessive

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[41] Ibid., 11.

[42] Ibid., 33.

[43] Hitchens, "Monsters and Shadows," 23.

[44] Chun, *Shooting Down a Star*, 36.

[45] Lieutenant General Michael D. Maples, US Army, Director, Defense Intelligence Agency, "Current and Projected National Security Threats to the United States," Statement for the Record, Senate Armed Services Committee, 27 February 2007, (Washington, DC: Government Printing Office, 2007) 27.

financial resources or a high-tech industrial base. These efforts include denial and deception, electronic warfare or signal jamming, and ground segment physical attack."[46]

Because destructive ASATs currently require expensive and specialized resources and an attack upon a space vehicle would necessarily be viewed as an act of war, any unrestricted space war in the next five years would, by definition, occur between peer or near-peer competitors and would most likely involve major combat operations. This will not always remain the case, however. An increasing number of states are exploring space utilization. Concurrently, many nations are developing military doctrine to go hand in hand with civil space exploitation. Several states, most notably China, Russia, America and several EU members are militarizing space and view their space capability as critical to national security.[47]

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[46] Ibid., 27.

[47] Collard-Wexler, *Space Security Index 2004*, 128.

Chapter 2 – Offensive Counterspace Threats to American Space Capability

Early Counterspace Development

As previously mentioned, only a handful of nations have committed the resources and effort necessary to extend war into the realms of outer space. The first nations to field a credible kinetic ASAT were the U.S. and the Soviet Union in the 1960s using nuclear-tipped ballistic and direct ascent missiles designed to provide a devastating electro-magnetic pulse, a side-effect of a high altitude nuclear detonation (HAND), which indiscriminately disables numerous satellites at once.[48] The propagation of the nuclear effect enabled the interceptor to only have to detonate within a forgiving vicinity of the target satellite to achieve desired effects thus mitigating the challenge of a complex precision guidance system. The Soviet Union and the U.S. further refined discriminate ground-launched ASAT capability by developing co-orbital kinetic kill ASATs from the late 1960s through the mid-1980s.[49]

The U.S. and the Soviet Union fielded second generation discriminate air-launched co-orbital ASATs during the mid-1980s.[50] The third generation of ASATs in seemingly perpetual development since the late 1980s by the U.S., Russia and now China are ground-based laser ASATs with ability that ranges from temporarily denying sensors (dazzling) to permanently disrupting a remote sensor (blinding) to inflicting physical damage to a satellite (destructive ASAT). China has simultaneously pursued ground-based second generation kinetic-kill ASAT technology from the mid-1990s to present.

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[48] Grego, *Space Weapon Basics*, 2

[49] Ibid., 2-3.

[50] Ibid., 3-4

Contemporary Counterspace Threats to American Space Dominance

Over the past five years there have been numerous advances made by America's traditionally adversarial nations in the arena of counterspace technology. The proliferation of laser and radio-frequency technology is of increasing concern for the U.S. every day. The technology required to dazzle or disrupt is increasingly easy to obtain and becoming cheaper as well. ASAT technology is following the pace of computer growth and it is simply a matter of time before several nations have the capability to seriously degrade American space dominance or completely deny America's space advantage all together. The U.S. Department of State (DoS) 2007 *Study on Space Policy* recently remarked that, "Threats to U.S. space assets, both from the ground and in space, are rapidly growing quantitatively and qualitatively. The United States does not have the luxury of assuming that its space assets will be available wherever needed."[51] The theme of this warning cannot be underestimated. As mentioned previously, America is critically reliant upon the advantages accrued from space dominance.

The DoS study also urged, "Survivability of our space assets in a deliberately hostile environment must be a requirement along with improved capability. Understanding and responding to threats to civil, commercial, and national security space assets is a vital national interest of the United States."[52] In order to prepare for the threats accumulating throughout the world, the actors must be identified, the capabilities assessed and the intentions estimated.

The director of the Defense Intelligence Agency, Lieutenant General (LTG) Michael Maples, warned the U.S. Senate in 2007 that, "Several countries continue to develop capabilities that have the potential to threaten U.S. space assets, and some have already deployed systems with inherent anti-satellite capabilities, such as satellite-tracking laser range-finding devices and

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[51] United States State Department, *Study on Space Policy*, 4.

[52] Ibid., 4.

nuclear armed ballistic missiles."[53] LTG Maples added that "A few countries are seeking improved space object tracking and kinetic or directed energy weapons capabilities."[54] The most notable potentially adversarial nations to which he is referring are India, Iran, North Korea, Russia and China. Although it is estimated that as many as thirty nations may have some form of ground-based laser ASAT capability to dazzle or potentially disrupt U.S. remote sensors, these five countries have undertaken dedicated efforts to build or acquire an operational destructive OCS system. This paper will examine each adversary threat in the order listed above. Keep in mind that most nations are not working in a complete vacuum concerning the development of space technologies (specifically destructive and disruptive ASAT technologies). Most nations work in concert sending experts around the globe to share notes and exchange ideas. Direct proliferation between adversary nations has taken place. Such interactions have been noted where public documents bring this activity to light.

India

As of 2008, there is no public evidence of a fielded operational ASAT system in India. There have been, however, clear steps taken by India toward that goal. India has the desire and has significant potential to field a credible destructive ASAT soon. The Indian Defence Ministry has publicly stated that it has a full appreciation of the importance of space exploitation and it also fully realizes that it must have a means to counter adversarial space exploitation in order to protect its drive toward greater regional hegemony.[55] The Indian military is also in the process of setting up a separate space command, labeled "Aerospace Command," which would have the

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[53] Maples, *Current and Projected National Security Threats*, 27.

[54] Ibid.

[55] Steven Lambakis, *On the Edge of Earth: The Future of American Space Power* (Lexington, KY: University Press of Kentucky, 2001), 199.

mission of OCS and DCS and is planned to be managed under the Indian Air Force.[56] This organizational change to the command and control structure of India reflects the evolving space technologies in India.

India views China as its most pressing challenger and threat.[57] The 2007 Chinese co-orbital kinetic ASAT test made many defense and policy officials in India nervous. Fears were already high concerning China and other potential rivals to Indian space capability, namely Pakistan.[58] India also recognizes that there is a potential for adopting an adversarial role concerning the U.S.[59]

As a result, over the past five years, India has been dedicating resources toward building and protecting both its civil and military space capabilities. It has a partnership with Israel to acquire and produce space-based remote sensing satellites, both for civilian application and military intelligence gathering.[60] Reports indicate that India is funding research into domestically produced disruptive and destructive ASAT systems.

The Center for Defense Information released a report detailing the extent of India's ASAT research in 2004. The report highlighted that while none of the systems were beyond conceptual research stages at the time, New Delhi was exploring technological developments involving ground-based laser ASATs, space-based lasers and a "kinetic attack loitering interceptor."[61] Based upon current indications, these domestically produced ASAT programs are

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[56] BBC News, "India in Aerospace Defence Plan", BBC News, 28 January 2007, http://news.bbc.co.uk/go/pr/fr/-/2/hi/south_asia/6307875.stm (accessed 12 February 2008).

[57] Rajat Pandit, "China Missile Worries India," Times of India, 20 January 2007, http://timesofindia.indiatimes.com/articleshow/1323752.cms (accessed 22 November 2007)

[58] Ibid.

[59] Chun, *Shooting Down a Star*, 52.

[60] Simon Collard-Wexler, Thomas Graham Jr. et al. *Space Security 2006* (Waterloo, Ontario: Space Security Index, July 2006), 112.

[61] Jeffrey Lewis, *What if Space Were Weaponized? Possible Consequences for Crisis Scenarios*, (Washington, D.C.: Center for Defense Information, July 2004), 29.

expected to take at least a decade before coming to fruition, assuming there is no outside assistance. If India should desire to accelerate OCS capabilities, specifically because of rising tensions surrounding Pakistan or China, it may well obtain outside assistance that could drastically shorten the timeline for a credible Indian disruptive or destructive ASAT to be fielded.

There is speculation that India, like any nuclear power with significant ballistic missile technology, could resort to an indiscriminate HAND ASAT using a variant of its Satellite Launch Vehicle-3 (SLV-3) or a variant of the Agni ballistic missile. India's on-going ballistic missile development combined with the nuclear arms race against rivals China and Pakistan is of significant concern to the U.S. and indicates that India might already be capable of employing a crude HAND ASAT, if pressed.[62] India has already indicated a desire and potential willingness to utilize a discriminate destructive ASAT to protect its nuclear research programs.[63]

It is precisely that rhetoric that could make what is already a tense arms race spin out of control. Indian space experts have publicly supported and proposed developing or acquiring destructive ASATs. That call increases the tensions of its neighbors and provides the impetus for them to acquire OCS and DCS capabilities. The ultimate fear, reminiscent of the Cold War between the U.S. and the Soviet Union is that "A global competition that produced armadas of space weapons . . . could raise the risk of accidental nuclear war if, for instance, a whirling piece of space junk knocked out a spy satellite."[64] The precipitated nuclear war could severely impact U.S. LEO and MEO satellites even if the U.S. is not participating in the conflict.

[62] Chun, *Shooting Down a Star*, 52.

[63] Ibid.

[64] William J. Broad, "Look Up! It's No Meteor, It's an Arms Race," *New York Times*, 21 January 2007, Late Edition (East Coast).

Iran

Currently there is no public evidence that Iran possesses any disruptive or destructive ASAT capability. Iran is also not expected to indigenously produce any such system in the foreseeable future.[65] The concern, however, is a marginalized and threatened Iran would not necessarily have to domestically produce its own ASAT system. It is not unreasonable to suspect that disruptive or destructive ASAT technology could be proliferated to Iran by sympathetic nations seeking to reap the benefits of Iran degrading U.S. space dominance while simultaneously enjoying plausible deniability of the act. China is a perfect candidate for that role. Iran has been working closely with North Korea to help accelerate the Iranian space program capabilities.[66] It is conceivable that Iran could obtain North Korean destructive ASAT technology or use North Korea as a broker to obtain Chinese destructive ASAT technology.

Iran desires to increase its prestige throughout the Middle East. It is clearly working on establishing a space presence to obtain that goal.[67] Iran is very aware of the advantage provided by space exploitation. It has built and orbited its own remote-sensing satellite and is working to produce a domestic launch capability.[68] Iran has countered Voice of America signals being broadcast via satellite into Tehran using ground-based electronic warfare jamming techniques which is one of the first steps toward producing an OCS capability.[69]

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[65] Yiftah S. Shapir, "Iran's Efforts to Conquer Space," Jaffee Center for Strategic Studies, *Strategic Assessment* 8, No. 3 (November 2005), http://www.tau.ac.il/jcss/sa/v8n3p2Shapir.html, (accessed 12 February 2008).

[66] Craig Covault, "Volatile Mix: Iran-North Korean Missile Collaboration Grows as Covert Chinese ASAT Possibility Lingers," *Aviation Week and Space Technology*, 5 March 2007, 98.

[67] John B. Sheldon, "A Really Hard Case: Iranian Space Ambitions and the Prospects for U.S. Engagement", *Astropolitics* 4, No. 2 (Summer 2006): 242.

[68] Craig Covault, "Iran's Sputnik: Shia Islamic Satellite Set for Liftoff on ICBM Cloaked as Space Booster; Tehran Looks Poised to Try Satellite Launch With Long-Range Missile Implications," *Aviation Week and Space Technology*, 25 January 2007, 24.

[69] Collard-Wexler, *Space Security 2006*, 138.

Realistically, however, Iran has stumbled greatly in its attempt to domestically develop a space capability. Iran had to rely upon a Russian launch to orbit its domestically built Sina-1 satellite in 2005.[70] Evidence suggests, however, that Iran is continuing research converting the Shahab-3 missile into a SLV, re-designated the Shahab-4 SLV, and conducted a successful test launch to near-orbital altitudes in early 2007.[71]

If Iran should either procure or produce a nuclear weapon capability and develop a means to mate a nuclear warhead to a ballistic missile then it would have the same crude HAND ASAT capability that India most likely already possesses. The likelihood of such an event occurring is unknown. Iran is currently estimated to have Intercontinental Ballistic Missile (ICBM) capability by 2015 and already has a Medium Range Ballistic Missile (MRMB) based on the North Korean No-Dong missile.[72] Unfortunately, other disruptive and destructive ASAT technologies cannot be completely ruled out in the near term due to proliferation concerns centered around Iran's partnership with North Korea.

North Korea

As of early 2008, North Korea does not posses a discriminate ASAT capability. They do continue to pursue critical advances in space technologies and are a prime candidate for proliferation of ASAT technology from China. The biggest fear of the U.S. is that North Korea, who already posses nuclear weapons, will emulate the HAND ASATs of the 1960s by placing a nuclear warhead on either the yet to be proven Taepo Dong-2 ICBM or the shorter range No-

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[70] Ibid., 112.

[71] Covault, "Iran's Sputnik," 24.

[72] Steven Lambakis, "Leveraging Space to Improve Missile Defense," *High Frontier Journal* 3, No. 2 (March 2007): 25-26.

Dong MRBM.[73] It is feasible that such a tactic could be accomplished now assuming that North Korea is capable of mating their nuclear warheads to either of the missiles. North Korea would have dramatically less to lose than it would gain by producing an indiscriminant LEO EMP to degrade the U.S. space advantage, severely reduce American military capability, and disrupt the American economy at the same time.[74]

Russia

Russia is the largest and most capable OCS nation in the world. Russia has a long history concerning ASAT development. It is the only nation to currently possess an operational conventional destructive ASAT system.[75] According to DoS reports, the OCS capabilities that Russia has openly admitted to and publicly tested are, "laser, radio frequency, jamming, and electro-magnetic pulse (EMP) systems that could be employed against U.S. space capabilities."[76] Russia still bases its HAND anti-ballistic missile ASATs in a defensive ring around Moscow. The HAND missiles are intended to defeat an incoming ICBM salvo but could also be used against LEO and potentially MEO satellites."[77]

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[73] John Parmentola, Chief, Advanced Operations and Systems Division, *High Altitude Nuclear Detonations (HAND) Against Low Earth Orbiting Satellites (HALEOS)*, (Washington DC: Advanced Systems and Concepts Office, Defense Threat Reduction Agency, April 2001), 7.

[74] Excepting the political backlash and the international outrage of all LEO satellites being affected. However, from a strict space capabilities cost-benefit analysis, North Korea is clearly the winner in this scenario. Presumably there would be other factors at play for the North Koreans to attempt this course of action that would also tend to mitigate the worries over political fallout from employing a HAND ASAT.

[75] Russia's Co-orbital ASAT system is the only operationally fielded conventional (non-nuclear) system that has been placed in operational (post-testing) service. The Chinese destructive ASAT shot in January 2007 was the latest of four tests and as of the writing of this paper there is no open source evidence that China has fielded an operational system based on either the KT-1 or KT-2 missiles. Additionally, there is no compelling open source evidence that China has yet fielded a destructive ground-based laser ASAT system either

[76] United States State Department, *Study on Space Policy*, 4.

[77] Steven Lambakis, "Space Control in Desert Storm and Beyond," *Orbis* 39, No. 3 (Summer 1995): 423.

Russia is hardly resting upon its laurels. In recent years the Russian military has gone through a rapid and dramatic renewal effort reminiscent of the heyday of President Reagan's military improvements in the mid-1980s.[78] Russia is specifically renewing efforts to update and improve current OCS systems. One such example is the recent development of the S-400 Air Defense System (NATO codename: SA-21 Growler). While officially not designed to specifically counter ICBMs, the Commander of the Russian Air Defense Forces Special Command, Colonel-General Yury Solovyov, made remarks that the S-400, "could also be used for limited purposes in missile and space defense."[79] As an air defense system it is mounted on trucks and is capable of moving. This makes it highly mobile and significantly reduces the physical infrastructure required to support the missile system. The result is that the S-400 is readily exportable and deployable. In fact, the Russians are expecting to start exporting the system concurrent with their own fielding within the next two years.[80] Although it is likely that the S-400 will be very expensive and only large countries like China will be able to afford it initially, there is still a chance that it could be proliferated to smaller nations interested in doing almost anything to obtain a limited destructive ASAT capability, such as Iran or North Korea, or even an NGA with vast financial resources. The likelihood of ASAT proliferation to an NGA directly from Russia is, thankfully, fairly remote.

China

The Chinese OCS program represents the most likely adversarial capability threatening American space dominance today. China has both demonstrated a willingness to directly

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[78] Fred Weir, "Russia Intensifies Efforts to Rebuild Its Military Machine", *The Christian Science Monitor*, 12 February 2007.

[79] "Russia to Export S-400 Air Defense System from 2009", *Space Daily*, http://www.spacedaily.com/reports/Russia_To_Export_S_400_Air_Defense_System_From_2009_999.html (accessed 12 February 2008).

[80] Ibid.

challenge American space dominance and has illustrated the capability to do so. Of all the potential adversary nations examined China has the greatest likelihood of developing into a large-scale, peer to peer or near peer conflict that would likely involve unrestricted space warfare with the capacity to severely cripple American space capability.

China has sent mixed messages when it comes to the acceptability and utility of ASATs. Some defense experts in China have argued that, "space warfare with a superpower should be a Chinese concern, and that China needs anti-ASAT technology, smaller satellites to reduce vulnerability and first strike capabilities in space."[81] This, however, is not China's official state position. China has lobbied for a treaty banning weaponization of space for over two decades. It has sponsored and supported many efforts in the UN Conference of Disarmament to adopt measures that would avoid or mitigate an arms race extending into outer space.[82]

By contrast, internal Chinese actions and rhetoric do not follow a non-weaponization and non-ASAT path. Chinese UN ambassador Hu Xiaodi explained at a 2001 meeting that the impetus driving the Chinese to push for negotiations concerning space weaponization was in reaction to the U.S. abrogating the Anti-Ballistic Missile treaty. He commented that such a move by the U.S. was interpreted as a sign that America was moving to develop missile defense and outer space weapons systems.[83] Therefore, much like the Soviet and American rhetoric of the mid-1960s extolling the necessity to ban nuclear confrontation, the Chinese are looking to gain positional parity with American space dominance while working behind the scenes to develop peer capability. China has been relatively successful in catching up, if not surpassing the U.S. in certain aspects of OCS.

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[81] Hitchens, "Monsters and Shadows," 25.

[82] Ibid., 24.

[83] Hu Xiaodi, Statement by Mr. Hu Xiaodi Ambassador for Disarmament Affairs of China, Plenary of the 2002 Session of the Conference on Disarmament, Geneva, 7 February 2002, 3, http://www.reachingcriticalwill.org/political/cd/speeches02/chi070202cd.pdf (accessed 12 February 2008).

Chinese research exploring various ASAT technologies is publically prolific. The U.S.-China Economic and Security Review Commission reported to Congress in 2007 that, “Using open source material, the commission's researchers found 30 Chinese ASAT concepts have been formulated by the People's Liberation Army. They include several involving ‘covert deployment of a sophisticated anti-satellite weapons system to be used against the U.S. in a surprise manner.’”[84] The January 2007 direct-ascent kinetic ASAT demonstration conducted by China destroying their own LEO weather satellite is the most visible and notable measure of their progress in these endeavors.[85] But China is hardly content with only one means to destroy or disrupt satellites. The Office of the Secretary of Defense concluded in a 2007 report to Congress that, “In addition to the direct ascent ASAT program demonstrated in January 2007, China is also developing other technologies and concepts for kinetic (hit-to-kill) weapons and directed-energy (e.g., lasers and radio frequency) weapons for ASAT missions.”[86] China has recently shown a great deal of interest in the evolving field of microsatellites which may offer a vast array of ASAT options including the concept of space mines or sleeper co-orbital ASATs.

China has a clearly demonstrated rationale for developing such a robust OCS capability. Chinese Colonel Yuan Zelu explained in a People’s Liberation Army National Defense University book that, “[The] goal of a space shock and awe strike is [to] deter the enemy, not to provoke the enemy into combat. For this reason, the objectives selected for strike must be few and precise . . . [for example] on important information sources, command and control centers, communications hubs, and other objectives. This will shake the structure of the opponent’s operational system of organization and will create huge psychological impact on the opponent’s

[84] Covault, “Volatile Mix,” 98

[85] Office of the Secretary of Defense, *The Military Power of the People’s Republic of China, Annual Report to Congress*. 110th Congress, 1st Session, 2007, 21.

[86] Ibid., 21.

policymakers."[87] China is looking to gain the initiative in any space war by striking first and striking hard. It does not intend to get embroiled in a protracted space war, but it does want to obtain a decisive advantage early on concerning space dominance involving a space power like the U.S.

Unfortunately, the threat of China's ASAT programs extends well beyond a conflict confined to Chinese territory. Much like Russia, China has been rapidly creating and expanding markets in which to export military technology. Chinese ASAT technology is clearly on the menu for potential customers. China has already exported and proliferated ballistic missile and space launch technology while concurrently acquiring new technologies abroad to improve their domestic capability in space.[88] It is for this reason that Chinese ASAT research and development represents the clearest and most present challenge to American space assets. Additionally, it is a tested and fielded technology. The proliferation of more ASATs to countries that might directly challenge America's presence in space is only going to complicate future counterspace efforts if the U.S. does not work very hard to keep pace.

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[87] Ibid., 21.

[88] Chun, *Shooting Down a Star*, 55.

Chapter 3 – Defensive Counterspace Options: Protecting America's Space Capability

Defensive Counterspace Doctrine

USAF counterspace doctrine manual (AFDD 2-2.1) delineates three major aspects of satellite protection: deterrence, defense and recovery. Of the three, the largest effort (and cheapest expenditure of national resources) lies with deterrence. Ironically, as mentioned above, it is American space dominance and policy that is exacerbating the threat environment against U.S. space hegemony causing adversarial nations to pursue greater OCS capabilities.

The 2006 *NSP* lists several principles concerning space activity and programs. Among those principles there is a declaration of opposition to "the development of new legal regimes or other restrictions that seek to prohibit or limit U.S. access to or use of space."[89] This would seem to be rather inflammatory rhetoric to any nation worried about America's continued militarization and potential weaponization of space. The *NSP* continues, "Proposed arms control agreements or restrictions must not impair the rights of the United States to conduct research, development, testing, and operations or other activities in space for U.S. national interests."[90] Clearly, the political door is wide open in this policy nearly demanding international acceptance of any militarization or weaponization of space the U.S. might choose. That position exacerbated international concerns when the U.S. abrogated the Anti-Ballistic Missile Treaty in 2001. It would seem to be more aggressive and at cross purposes with the deterrence facet of defensive space doctrine. It is that very reality that requires the U.S. military to explore a robust DCS capability. It is also what compels USAF doctrine to explain that while deterrence is the primary means of protection for space assets, it will only be effective, "with an emphasis on a

[89] President, *NSPD-48*, 2.

[90] Ibid., 2.

demonstrated national policy of appropriate response to threats or attacks and the national will to responds to such threats or attacks."[91]

The 2006 *NSP* provides the strategic guidance for developing DCS technologies. First the *NSP* declares, "the rights of passage through and operations in space without interference."[92] Commensurate with that right, the U.S. reserves the option to legally, "preserve its rights, capabilities, and freedoms of action in space; dissuade or deter others from either impeding those rights or developing capabilities intended to do so; take those actions necessary to protect its space capabilities; respond to interference; and deny, if necessary, adversaries the use of space capabilities hostile to U.S. national interests."[93] These principles are further clarified in the National Security Space Guidelines of the *NSP*.

The Secretary of Defense (SECDEF) and Director of National Intelligence are charged with the responsibility to, "Develop and deploy space capabilities that sustain U.S. advantage and support defense and intelligence transformation."[94] The SECDEF is further given the lone responsibility to, "Develop capabilities, plans, and options to ensure freedom of action in space, and, if directed, deny such freedom of action to adversaries."[95] DoD Space Policy echoes the national policy by, "Ensuring the United States' ability to conduct military and intelligence space and space-related activities."[96] All this direction sets the stage for DCS. Because the USAF is the designated lead agent for DCS, it falls upon them to chart the course along the DCS path of development. USAF doctrine concerning DCS was discussed in the Introduction of this monograph.

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[91] Air Force, AFDD 2-2.1, 25.

[92] President, *NSPD-48*, 1.

[93] Ibid., 1-2.

[94] Ibid., 4.

[95] Ibid.

[96] Department of Defense, *Department of Defense Directive (DODD) 3100.10, Space Policy*, (Washington D.C.: Government Printing Office, 9 July 1999), 7.

Fielded Defensive Counterspace Programs

The majority of the DCS effort is focused upon protecting the largest majority of the space infrastructure that is also, consequently, the most vulnerable (ground stations, command centers, digital links, and others). Ground stations are viable targets not only for conventional attacking forces but for guerrilla units or even space-based weapons. The electronic links between the satellite and ground nodes are a highly vulnerable portion of any contemporary space system as evidenced by the GPS jamming encountered during Operation Iraqi Freedom and the various sources of telemetry interference encountered either from deliberate or innocuous sources every day.[97]

Most of the passive defense measures delineated in AFDD 2-2.1, *Counterspace,* involve the terrestrial nodes of a space system.[98] On the other hand, many of the active defense measures listed involve the space nodes of a space system. Until recently, very little could be done (nor did it need to be) to defend the satellite node from disruptive or destructive attack. For the most part, space provided a sanctuary for anyone to freely transit their satellites with impunity. Except for the threat of a global thermonuclear war in which one of the superpowers employed a HAND ASAT to deny the use of space, there has not really been a significant threat against the space-borne node of a space system. That sanctuary is quickly becoming less secure. It is a concern of the Commander of the Air Force Space and Missile Systems Center, Lieutenant General Michael Hamel, when he remarked that recent USAF acquisitions of space projects look "at space

[97] Bruce M. DeBlois, et al., "Space Weapons-Crossing the U.S. Rubicon", *International Security*. 29, No. 2 (Fall 2004): 57.

[98] This is not to suggest that passive defensive measures are not used on satellites. On the contrary there are constant decisions and trade-offs concerning the weight of protective shielding, equipment, etc., balanced against the perceived threat and likelihood of attack. Until recently, it has been a reasonable gamble to opt in favor of lighter weight and reduced complexity except for the most critical of satellites, usually viewed in the context of a nuclear exchange scenario. In such a scenario the loss of lesser critical satellites would pale in comparison to terrestrial issues.

protection as something that has to be integrated and designed into the system, the satellites, the control links, the ground-control system, [and] the user equipment."[99]

As noted above, three nations now have developed and tested destructive kinetic ASATs. Several more nations have acquired proven ground-based disruptive and destructive laser ASAT technology. The U.S. may no longer (and certainly will not in the future) have the luxury of orbiting satellites without at least the implied threat of retaliation. From that perspective, the calculus involved in deciding what protection a given space system requires overall has changed dramatically.

Today's active DCS measures to defend a satellite cannot react within the timeline associated with a single orbit direct ascent kinetic intercept, much less within the nearly instantaneous intercept timeline of a ground-based laser attack. Modern direct ascent kinetic ASAT intercepts occur within less than one full LEO orbit, which equates to something less than 100 minutes and may be as short at 30 minutes. China's 2007 ASAT intercept occurred at only 530 miles up and 250 miles (4 degrees) over from the launch site.[100] Depending upon the capability to hide a microsatellite, it would be possible to also position a co-orbital parasitic satellite that would effectively provide no warning what-so-ever to ground stations until the satellite was already disabled. The timeliness of responding to a ground-based laser attack precludes many active traditional SACC measures (bombing the offending site for example) before the damage is already incurred on the American space system. "At the speed of light--300,000 kilometers per second (km/s)--a laser's propagation from Earth to space is essentially instantaneous, although it would take minutes or seconds to aim the laser in addition to whatever

[99] Michael Sirak, "Air Force Mulls Path Ahead for Protecting Satellites", *Defense Daily* (25 September 2007): 21.

[100] Craig Covault, "Chinese Test Anti-Satellite Weapon", Aviation Week.com, 17 January 2007, http://www.aviationweek.com/aw/generic/story_generic.jsp?channel=awst&id=news/CHI01177.xml (accessed 12 February 2008).

"burn time" was necessary for destructive effect once the laser had focused on its target."[101] Damage could occur from a short-pulse laser within a millionth of a second.[102]

The responsiveness of any sort of active DCS measure, whether it be maneuvering the satellite, changing the configuration of the system to protect sensors, or relying upon traditional SACC measures such as using a cruise missile to destroy a ground-based ASAT is severely non-responsive and would not be an effective defense to save the satellite. Even advocates of space-based weapons admit that co-orbital space weapons would not be responsive enough to provide adequate protection. "As a defense, airplanes or cruise missiles would take hours or days to act, and intercontinental ballistic missiles, or ICBMs (assuming the needed accuracy could be achieved) up to forty-five minutes. But even a kinetic-energy weapon (such as a long-rod projectile) stationed in orbit would require some tens of minutes to arrive at a suitable orbital position, and five minutes to fall from a typical altitude of 450 kilometers."[103] Some space control experts counter that traditional offensive SACC measures would be effective after absorbing acceptable losses initially. "A single enemy ground-based laser could destroy only satellites within its line of sight, and the time necessary for other satellites to move into view would allow the United States time to target the site with conventional weapons, if its precise location were known. Consequently, an adversary would need multiple ground-based lasers or significant ground-based laser mobility to destroy many U.S. space assets."[104] With the most recent proliferation of laser technology and the increasingly lowered cost of building high powered lasers, it is conceivable that a nation like China could very well field such a robust

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[101] DeBlois, et al, "Space Weapons," 58.

[102] Ibid., 58.

[103] Ibid., 58.

[104] David A. Fulghum and Robert Wall, "Satellite Self-Protection Gains Added Attention," *Aviation Week and Space Technology,* 28 October 2002, 68.

threat. The discussion concerning effective active DCS methods is further complicated by the difficulty of detecting and properly characterizing an attack upon a given target satellite.

Attack detection and characterization represents the fundamental stumbling block for any active DCS measure to be executed and be effective. Obtaining such information is characterized by the USAF as acquiring space situational awareness (SSA), and it is the highest priority for satellite defense research and development today per the direction of Secretary of the Air Force, the Honorable Michael Wynne.[105] The program that encompasses the efforts to obtain SSA is RAIDERS (Rapid Attack Identification Detection and Reporting System).

Because of the sensitive nature of any space defensive system, very little open-source information exists concerning RAIDERS or other similar programs. However, there are some generic descriptions that explain the goal of the RAIDERS program. Part of the goal of the program is to obtain near-real time notification of a pending attack including the type and the origin of the attack.[106] Unfortunately, this has proven to be more difficult than once anticipated. Identifying the source of a satellite's degradation is extremely difficult because of the inherently inhospitable nature of outer space. "Space contains a myriad of threats, ranging from orbiting debris, sun spot activity to technical malfunctions, which can be confused with hostile attacks."[107] The goal of RAIDERS is to distinguish between what is an accident or natural occurrence and what is a hostile attack.

It will require a myriad of sensors including the satellite itself, ground-based tracking systems and even space-based situational awareness sensors. Unfortunately, several programs

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[105] Sirak, "Air Force Mulls Path Ahead", 21; It has also been a priority for military commanders, including former commander of United States Space Command and current commander of United States Strategic Command, General Kevin P. Chilton, reference his remarks in same article.

[106] Fulghum, "Satellite Self-Protection," 69.

[107] Joe Pappalardo, "Air Force Mulling Over Programs to Kill, Protect Satellites in Space Warfare," *National Defense Magazine*, December 2004, http://www.nationaldefensemagazine.org/issues/2004/Dec/AirForceMulling.htm, (accessed 12 February 2008).

involved in updating SSA have recently either been cut outright or lost funding priorities. Most affected programs are modernization efforts for the ground components of SSA. The space-based portion of SSA (Space Based Space Surveillance, SBSS) is not expected to be operational until at least 2012, at the earliest.[108] These sorts of budgetary constraints have contributed to an overall lack of SSA which concerns senior space leaders greatly causing them to label it the "single greatest weakness of the U.S. military space program."[109]

As of 2002, some satellite programs, (Defense Support Program and National Reconnaissance Office satellites) did possess a rudimentary threat detection system.[110] Any sort of assessment or details of the capability of such systems is not available at an unclassified level and there is no open-source information that the detection capability has been proliferated to additional satellite programs to date, indicating that many equally critical satellite systems have no active threat detection measures at all.[111] It is estimated that such systems cannot detect a physical attack upon the satellite. It can be equally assumed that civilian LEO satellites have no built in protection methods beyond what would be needed to survive in the natural environment of space.[112]

Overall, the inability to predict, detect, and characterize an attack against a military, much less against a civilian satellite, renders methods of protection such as maneuvering or satellite system configuration changes obsolete and impotent. Only passive defenses such as shielding or hardening are currently of any use in the LEO region against today's ground-based laser or direct ascent kinetic ASAT threats. The same applies for geosynchronous satellites when

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[108] Jon Kyl, Senator, "China's ASAT Test and American National Security," Remarks at The Heritage Foundation, *GlobalSecurity.org*, http://www.globalsecurity.org/space/library/news/2007/space-070129-kyl01.htm (accessed 12 February 2008).

[109] Sirak, "Air Force Mulls Path Ahead," 24.

[110] Fulghum and Wall, "Satellite Self-Protection," 68.

[111] DeBlois, et al., "Space Weapons," 56.

[112] Ibid., 56.

considering the threat ground-based lasers pose to highly sensitive sensor arrays. While there does not seem to be any responsive self-protection methods available for U.S. spacecraft today, there is hope that active satellite self-defense programs being examined and developed will be completed and fielded prior to actually being required. The problem is previous estimates for a fielding timeline requirement may have been overly optimistic, especially if the 2007 Chinese kinetic ASAT test and laser dazzling incidents are any indication of the future to come. The defensive methods in development need to be accelerated and given resources if they truly hope to achieve their goals of providing adequate satellite protection against disruptive and destructive ASAT attacks.

Dedication to Defensive Counterspace Strategies

Obviously the subject of space superiority is much more complicated than focusing strictly upon satellite self-defense measures in order to protect America's space capability. One of the most touted measures of reducing threat is the use of treaties and international agreements to reduce the threat to one's space systems. From an economic and cost benefit analysis point of view, treaties are the most efficient path to follow and are effectively free. There is an inherent problem relying upon such a method exclusively. First it would be nearly impossible to distinguish and verify that a fielded ICBM or MRBM is not also ASAT capable. Likewise, it has proven nearly impossible to restrict or embargo destructive ASAT capability, much less to deny a sovereign nation ICBM or MRBM ownership.

Arizona Senator and Republican Whip Jon Kyl intimated a realist's perception of the difficulty surrounding international agreements, "Once signed, [a space arms control agreement] could lull us into a false sense of security. Like so many other similar treaties, you don't need it for the countries who would comply, and it will be of no use for those who will cheat."[113] The

[113] Kyl, "China's ASAT Test."

Senator also explained the paradox the U.S. has with regards to China and space threats. "The Chinese profess peaceful intent and uncategorical opposition to space weapons. At the same time, they are developing and testing a multi-layered space warfare capability. The U.S. on the other hand, repudiates arms control, publicly asserts its rights to deny space access to our enemies, and yet seems ambivalent towards the means of exerting that control."[114] Arguably reliance upon a Wilsonian treaty optimism to prevent threats to America's satellites is not panning out with China in a way conducive to U.S. interests.

The second most relied upon method of protecting satellites is simply to classify information about the satellite and include balanced defensive measures such as electromagnetic shielding, maneuver capability, or configuration changes. As previously mentioned, by the time a modern laser attack or direct-ascent attack has been witnessed, processed, and finally characterized as an attack, any active options available to protect the satellite have most likely become moot. Passive measures today are incapable of fully protecting against a direct-ascent kinetic kill intercept or from a high-power ground-based laser ASAT, especially for a LEO satellite.[115] Even if they could prove to be effective, declining budgets and SLV booster lift capacities force compromise, inhibiting adequate physical protection measures against modern ASAT threats.

Budgetary commitments for DCS efforts have consistently declined. "The budget for all three elements [Space Situational Awareness, Defensive Counterspace and Offensive Counterspace] added up to less than $500 million for fiscal year 2007, less than one half of one percent of the total Air Force budget."[116] Several estimates show that the U.S. military is spending one-tenth of the amount of money analyzing threats to satellites than it did in the early

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[114] Ibid.

[115] Space Security Index Governance Group, *Space Security 2007* (University of Waterloo: Ontario, Canada, August 2007), 114; DeBlois, et al., "Space Weapons," 58.

[116] Kyl, "China's ASAT Test."

1980s.[117] Procurement estimates for the fiscal year 2008 counterspace budget request totaled around $373.7 million.[118] It remains to be seen if all of the proposed counterspace programs will receive the fully requested funding. Historically, they have not. This is a situation lamented by Senator Kyl: "Even though the budget environment is tight and resources are not unlimited, America can afford to defend our vital national interests in space. In fact, we can't afford not to."[119]

Despite the declining budgets, the USAF has remained focused upon trying to develop counterspace capabilities for the future. *The Air Force Transformation Flight Plan* states,

> The ability to protect vital space systems is essential to ensure that an adversary cannot disrupt, deny, or destroy America's ability to exploit space-based C4ISR assets as previously described. This capability encompasses: (1) space-based space surveillance systems that provide details of space objects unattainable by ground-based systems; (2) an attack detection and reporting architecture capable of detecting, characterizing (identify and geo-locate), and reporting attacks on space systems and of assessing the resulting mission impacts; (3) active on-board capabilities to protect friendly space systems from man-made or environmental threats; and (4) adequately protecting key ground systems, to include backup command and control capabilities. This transformation will be enabled by both material solutions as well as doctrinal and organizational changes.[120]

Of the multiple options presented above, the *USAF Transformation Flight Plan* identifies that the majority of effort, when practical, would "be on denying adversary access to space on a temporary and reversible basis."[121] The contemporary political environment is not amenable to a dedicated research effort based upon permanent destruction of adversarial space assets yet. Additionally, the U.S. has learned that direct ascent kinetic kill vehicles are highly disruptive to

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[117] Jonathan Howland, "China's Anti-Satellite Program Alarming," The Jewish Institute of National Security Affairs Online, 1 March 2007, http://www.jinsa.org/articles/view.html?documentid=3716 (accessed 12 February 08).

[118] Department of the Air Force, *Procurement Program-Fiscal Year (FY) 2008/2009 Budget Estimates-Other Procurement*, (Washington D.C.: Government Printing Office, February 2007), xi.

[119] Kyl, "China's ASAT Test."

[120] Headquarters Air Force, *The U.S. Air Force Transformation Flight Plan*, (Future Concepts and Transformation Division, Washington D.C., November 2003), 61.

[121] Ibid.

surrounding non-targeted satellites and orbits because of the debris field they create upon completion of a successful intercept, a lesson re-emphasized by the debris field created by China's 2007 intercept that is threatening numerous satellites, including the International Space Station.

Table 1. USAF Key Programs/Future System Concepts.

Near-Term (until 2010): Counter Satellite Communications System, Counter Surveillance and Reconnaissance System, Rapid Attack Identification Detection and Reporting System, Single Integrated Space Picture, Space-Based Space Surveillance System, Space Control Range

Mid-Term (2010-15): Common Aero Vehicle, Compact Environmental Anomaly Sensor II ACTD, Communication/Navigation Outage Forecasting System ACTD, Orbital Deep Space Imager, Space Tracking and Surveillance System

Long-Term (past 2015): *Air Launched Anti-Satellite Missile, Ground Based Laser, Orbital Transfer Vehicle, Space-Based Radio Frequency Energy Weapon, Space Maneuver Vehicle, Space Operations Vehicle*

Source: Headquarters Air Force, *The U.S. Air Force Transformation Flight Plan* (Washington D.C.: Future Concepts and Transformation Division, November 2003), 62.

Unfortunately, the timeline associated with the transformation of counterspace capability does not readily synchronize with the evolving threat that was demonstrated in 2007 and which continues to proliferate at an alarming rate. Most capabilities planned for both the near and mid-term development (out to 2015) involves gaining and maintaining space situational awareness (see table 1). There is no suggestion of active (or for that matter, passive) DCS technology fielding until at least past 2015. And with the consistent delay in cutting edge technological development, it will most likely take longer before such capabilities can be realized, if ever. The challenge is if the adversaries will wait to challenge U.S. space dominance until after adequate protections have been put in place. Certainly, if an adversary nation wished to challenge U.S.

space dominance, waiting for defenses to get into place is not a good strategy, and therefore it would be logical to assume that the adversaries are not going to delay at all, if possible.

Chapter 4 – The Analysis of Doing More

Options and Decisions Ahead

Given that current efforts to proactively defend satellites from disruption or destruction are less than adequate, there are a few promising options currently in an initial development stage that could reap near-term benefits to protect satellites should an adversary choose to threaten the widespread use of ASATs against the U.S.

Micro-Satellite Decoy/Bodyguards

Micro-satellites (microsats for short) have been researched and developed for the past decade. There is a significant range of possibilities that microsats provide. There are commercial, academic and even military applications. The benefit of microsats is that they are quicker and consistently cheaper to build. They also take less effort to launch into space. There have been numerous successful launches of microsats, including some recent successful military test launches.[122]

Microsats could swarm to act like bodyguards for one or several spacecraft simultaneously, depending upon the proximity of the various platforms. The microsats would then, "monitor the area around a high-value vehicle and warn of an impending attack or even intercept an object."[123] Such a program is currently being developed by the Defense Advanced Research Project Agency (DARPA). Contract announcements were released in November 2007 asking for commercial bidding on research and development on a program called Tiny,

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[122] Justin Ray, "Experimental Military Microsatellites Reach Orbit", *Spaceflight Now*, 22 June 2006, http://www.space.com/missionlaunches/sfn_060622_mitex_launch.html, (accessed 12 February 2008).

[123] Fulghum and Wall, "Satellite Self-Protection," 69.

Independent, Coordinating Spacecraft (TICS).[124] The satellites would range from one to four kilograms and could be used for a range of activities not exclusive to satellite defense, although it is precisely that application DARPA is hoping to develop and demonstrate. The manager of DARPA's virtual space office, Lieutenant Colonel Fred Kennedy remarked December 2007 that there is a fifty-fifty chance of making TICS and the associated launcher a reality within five years, and certainly within ten years.[125] The bodyguard satellites could also be fitted with radio-frequency emitters in order to provide electronic jamming against the interceptor or to mimic the parent satellite it is trying to protect, making the bodyguard satellite a more promising decoy.[126] The rough cost estimates for a decoy system are estimated to be between one and ten percent of the overall satellite cost.[127]

Another promising satellite protection program currently in development is the Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS). Similar to TICS, ANGELS is designed to provide monitoring and threat detection in the local space surrounding a parent satellite. ANGELS is currently designed for autonomous operations at geosynchronous orbits.[128] Conceptually, ANGELS reaps the same advantages and possibilities as TICS does. The cost of the booster for ANGELS is commensurately greater in order to place it in GEO, but by comparison, the cost is still vastly smaller than for a full size payload at that orbit. Although ANGELS falls outside the scope identified in this monograph, the associated technology

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[124] Jeremy Singer, "Can Satellites Swarm to Defense? U.S. Researchers to Study Ways to Deploy Clusters of Tiny Spacecraft," *DefenseNews.com,* 10 December 2007, http://www.defensenews.com/story.php?F=3230517&C=airwar (accessed 12 February 2008).

[125] Ibid.

[126] Fulghum and Wall, "Satellite Self-Protection," 69.

[127] Wilson, "Threats to United States Space Capabilities," 45.

[128] Jeremy Singer, "Air Force Angels, Satellite Escorts Take Flight," *Space News*, 30 November 2005, http://www.space.com/businesstechnology/051130_airforce_angels.html (accessed 12 February 2008).

advances can be applied to LEO satellite protection, and therefore the transfer of the technology can aid in development of protection against a minimum or zero warning attack.

An inherent advantage of microsats and nanosats is the capability to renew or repopulate constellations quickly. Additionally microsats and nanosats enjoy a reduced acquisition and production cycle. Updated microsats could be built and launched within a few months using the latest technology available ensuring that satellite defense keep pace with emerging threats.[129] Because micorsats are a relatively proven concept, and additional applications are constantly emerging, the costs of the program, once mature, would be reasonably lessened by the bulk acquisition of components. Conceptually the basic components remain the same and the mission equipment changes; drastically shortening the test and development timelines.[130] Microsats could be clustered on today's larger boosters or be placed one or two at a time on smaller launching systems, such as a modified AIM-7 Sparrow air-to-air missile converted to place a microsat in LEO.[131] A secondary advantage of using smaller boosters like an AIM-7 is that launches would be indistinguishable from regular aircraft missile tests providing a means for covertly placing microsats into orbit and denying an adversary the knowledge that the bodyguards are there, if such an action were warranted.[132] Lastly, the biggest advantage of bodyguard satellites is that they can be sent to protect a satellite that is already on orbit. It is, therefore, the only means available to protect satellites launched three years ago. Other satellite self-defense measures will have to be included during manufacture on the ground, and will, for the most part, not be able to be added once the satellite is orbiting.

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[129] Fulghum and Wall, "Satellite Self-Protection," 69.

[130] Singer, "Can Satellites Swarm to Defense?"

[131] Ibid.

[132] Ibid. Take note that launching satellites into orbit without informing the UN of their presence is in direct violation of The Registration Convention. While the convention is vague enough to allow for a generic name for the satellite and an equally generic mission-purpose description when registering, clearly not registering the launch at all in an attempt to keep the bodyguards secret has very serious international law and treaty implications.

One critical downside to the use of micosats as bodyguards is the geometry of an intercept. “A collision with a multi-kilogram incoming satellite or projectile weapon traveling at 10 kilometers per second would have the equivalent destructive power of ten times that amount of TNT; a close-in intercept may deal a fatal collateral blow to the satellite intended to be protected.”[133] The destructive kinetic power or debris from a successful block could still damage or potentially destroy the satellite trying to be protected.

The kinetic kill vehicle would have the vast majority of its velocity vector aimed at the target satellite. A bodyguard microsatellite would be attempting to place its velocity vector against the kinetic interceptor in such a manner so as to divert the interceptor velocity vector (and all associated debris) away from the parent protected satellite. At the speeds involved, that is extremely difficult to accomplish.

There are ways to make bodyguards more successful in protecting the targeted satellite by accomplishing the bodyguard intercept farther away from the protected satellite and placing the velocity vector in such a manner so as to slow down the interceptor and debris velocity in order to place them in a lower and decaying orbit, which would protect the original target satellite.[134] Unfortunately, the secondary issue that is already associated with kinetic kill ASATs now comes into play and that is the unpredictable nature of the debris path and what unintended consequences may result from even a successful defeat of the original intercept.

Satellite Hardening

Considering that bodyguard satellites may not be able to stop all types of kinetic threats, and the protected satellite may still receive debris damage as a minimum, there are several means of hardening the shell of a satellite to withstand impacts from hypervelocity projectiles.

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[133] DeBlois, et al., “Space Weapons,” 60.

[134] Ibid., 60.

Hardening is considered by many to be the most effective defensive measure.[135] A few promising methods of shielding are already developed for the International Space Station (ISS) and have been applied to a few of its modules.[136] The basic protection against hypervelocity projectiles, such as a meteorite for the ISS is a type of shield called a whipple bumper.[137] Fortunately, work on whipple bumpers has been ongoing since the mid-1950s.[138] A whipple bumper is:

> A hypervelocity projectile shield which includes a hollow semi-flexible housing fabricated from a plastic like, or otherwise transparent membrane which is filled with a fluid (gas or liquid). The housing has a inlet valve-similar to that on a tire or basketball, to introduce an ablating fluid into the housing. The housing is attached by a Velcro mount or double-sided adhesive tape to the outside surface of a structure to be protected. The housings are arrayed in a side-by-side relationship and may be in layers and in an over-lapping relationship for complete coverage of the surface to be protected. In use, when a hypervelocity projectile penetrates the outer wall of a housing it is broken up and then the projectile is ablated as it travels through the fluid, much like a meteorite "burns up" as it enters the earth's atmosphere, and the housing is deflated. The deflated housing can be easily spotted for replacement, even from a distance. Replacement is then accomplished by simply pulling a deflated housing off the structure and installing a new housing.[139]

The bumper absorbs the energy of the hypervelocity projectile and dissipates it through deformation and ablative means. The National Aeronautics and Space Administration (NASA) also developed a couple modifications to the original whipple bumper design: stuffed whipple bumpers and mesh double bumpers.

Stuffed whipple bumpers are comprised of, "an outer bumper, a catcher, and one or more underlying layers of materials spaced between the bumper and the catcher to further disrupt and

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[135] Wilson, "Threats to United States Space Capabilities," 43.

[136] Emma A. Taylor, "Simulation of Hollow Shaped Charge Jet Impacts Onto Aluminum Whipple Bumpers at 11 km/s", *International Journal of Impact Engineering* 26, No 1, (December 2001): 773.

[137] Committee on International Space Station Meteoroid/Debris Risk Management, *Protecting the Space Station from Meteoroids and Orbital Debris*, (National Academy Press: Washington, D.C., 1997), 28.

[138] Ibid., 29.

[139] Michelle A. Rucker, *Ablative Shielding for Hypervelocity Projectiles*, (United States Patent Application 5,217,185, United States Patent Office, 8 June 1993), 1.

disperse the impactor. The advantages of this design are its improved performance over the standard Whipple design and, with some bumper materials (e.g., Nextel), its reduced production of secondary ejecta."[140] Additional material, almost like cotton padding, is placed between the outer part of the shield and the skin of the satellite in order to provide additional material to absorb the impact. Mesh double bumpers improve on stuffed whipple bumpers by controlling the secondary ejecta material in order to further protect the satellite from damage. Mesh double bumpers have, "metallic mesh disrupter in front of each of two bumpers."[141] This mesh material serves to further break up and dissipate the hyper-velocity projectile and its commensurate energy at impact.

As a rough rule of thumb, whipple bumpers increase the cost of a given satellite by approximately 10 percent. For a $1 billion satellite, thusly, the whipple bumpers to protect it would cost about $100 million. One suggestion to reduce the overall cost of the satellite is to protect only a given portion of it, usually the leading edge of the satellite (assuming that it is not spin stabilized), since many direct ascent intercepts are cross vector intercepts, indicating that the satellite and the ASAT move toward each other as opposed to the ASAT catching up to the targeted satellite.[142] Making the appropriate analysis against the expected threat is essential in order to place the bumpers in the correct location to afford protection while reducing cost.

Correctly estimating the threat to be protected against is also a pre-requisite for choosing the appropriate whipple bumper material and configuration. Unfortunately, whipple bumpers are not universally protective and require extensive specialization for various types of hypervelocity projectiles.[143] Different materials and configurations are used to protect against an ice hypervelocity projectile than are used for an iron core meteorite hypervelocity projectile.

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[140] Meteoroid/Debris Risk Management Committee, *Protecting the Space Station*, 29.

[141] Ibid,. 29.

[142] DeBlois, et al., "Space Weapons," 61.

[143] Meteoroid/Debris Risk Management Committee, *Protecting the Space Station*, 29.

Luckily, today, the range of variance among kinetic ASATs is very small and the technology is fairly specialized. That plays to advantage deciding what whipple bumper to install and in which configuration. Since the bumpers are designed to be replaced on orbit once an impact has occurred, it should be possible to modify, upgrade, or adjust the bumper plates within certain tolerances to keep pace with ASAT improvement and development.

Whipple bumpers do have other downsides in addition to cost. Whipple bumpers can fail to protect from low-velocity projectiles. Additionally, the bumper must be struck at a specific geometry-nearly perpendicular. An oblique impact will also make the bumper fail.[144] Conceptually, the purpose of the bumper in this case is to protect against a kinetic kill vehicle, which is by design hypersonic. All satellites have the concern of both hyper- and low-velocity impacts on a daily basis; low-velocity impact concerns are just the cost of business. The specific objective of protecting the satellite against a kinetic ASAT should be met.

Active Shielding

The previous two defensive methods are exclusive to protecting against kinetic-kill vehicles and do not protect against high-energy laser or directed energy ASATs. While configuration control measures can be taken to prevent dazzling and blinding, more can be done. Simple system configuration changes such as reducing the sensitivity of optics will not protect against a destructive laser ASAT. Even closing the internal iris will not necessarily protect the mission portion of the satellite from a destructive directed energy attack.

The addition of external shutters or deployable albedo shielding offers some hope. The deployment of the shielding could be made automatic. “Detection of the low-power aiming phase of the ground-based lasers would give time for closing a shutter to eliminate the exquisite vulnerability of the satellite’s focal plane. If deployed promptly, a thin metal shield (a parasol)

[144] Ibid: 29.

could provide substantial protection against a megawatt-class laser."[145] The deployment of a shield would have to occur rather quickly because "Short-pulse lasers can do damage in less than a millionth of a second."[146] The shielding would have to be deployed at immediate detection of the laser tracker. Fortunately, modest albedo shielding can protect non-imaging facets of satellites from laser heating. Unfortunately, for imaging sensors in LEO not only must you protect from laser heating over time, but from optic damage from extremely short bursts of energy.[147] For optical protection, a quickly deployable shield that can disperse the concentration of the laser energy may be enough.

When it comes to protecting from laser heating and various forms of directed energy, other types of shielding can be employed. One promising candidate under investigation by the AFRL currently is carbon nanotube membranes or Buckypaper. "Buckypaper is a thin membrane, approximately 10-15 μm thick, of roped carbon nanotubes which are incorporated with composite structure. . . . Buckypaper membranes are being investigated for aircraft lightning strike protection, but could have application to help satellites from electromagnetic events."[148] The membranes provide a sort of heat or energy dissipation through lateral dispersion of the energy, thus reducing the concentration of the focused energy and sloughing it off in a similar manner as a heat sink.[149] Additionally, Buckypaper acts as a shielding that can be manufactured at twice the hardness of diamonds or 250 times the strength of steel and most advantageously for satellites it is one-tenth the weight of steel.[150]

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[145] DeBlois, et al., "Space Weapons," 59.

[146] Ibid, 58.

[147] Ibid, 58.

[148] Joseph Huntington, "Improving Satellite Technology With Nanotechnology" (Blue Horizons Paper, Center for Strategy and Technology, Air War College, Maxwell AFB, Alabama, December 2007), 10.

[149] Bary Ray, "'Buckypaper': stronger than steel, harder than diamonds", Physorg.com, Florida State University, www.physorg.com/news7435.html (accessed 20 January 2008).

[150] Ibid.

Buckypaper can be combined with a form of nanotubes being investigated by AFRL in order to provide additional protection. The nanotube technology "transforms almost any polymer into a multifunctional material capable of carrying or dissipating significant electrical charge."[151] The beauty of the nanotubes is that they are far less dense than most electrical conductors, such as copper, and are therefore uniquely suited for space application where weight is of primary concern. The University of Dayton has been working with AFRL to perfect nanotube technology and the researchers feel that the technology is to the point of being commercially viable and can be produced in large amounts rather than the small lab amounts they have been researching.[152]

Another technology that AFRL is pursuing is the use of hollow silica particles to be used as a means of dissipating energy from the shielding of a satellite. The particles would be included into a pigment used to coat the satellite. The pigment technique "uses the low refractive index of a void (i.e., an empty space) to promote energy scattering. The surrounding silica shell is transparent to ultraviolet light and is space-stable. The result is a broader spectrum of reflectance that extends into the ultraviolet frequency range and increased space durability because the particles don't absorb ultraviolet energy."[153] The silica particles offer a broad range of protection against various directed energy ASAT threats in addition to natural threats associated with the orbital environment.

An additional advantage of these emerging energy dispersion technologies is that they can also be used to produce a faraday cage structure, which is used as a means of electro-magnetic pulse protection against HANDs. By being lighter and potentially cheaper, the nanotechnology offers the hope that protective shielding can be employed to a vast multitude of essential military and even civilian platforms for a highly reduced cost from conventional

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[151] Huntington, "Improving Satellite Technology With Nanotechnology", 11.

[152] Ibid: 11.

[153] Ibid: 11.

methods today. Expert estimates for hardening protection range from 2 to 5 percent of the total satellite cost.[154] Protecting multiple smaller distributed satellites may still remain overall cheaper than shielding one large platform.

Potential Defenses Summary

These satellite protection methods all have varying levels of probability of success. They are cutting-edge emerging technologies and none of them have yet to be thoroughly tested for satellite protection against ASAT threats. Some technologies will directly transfer; others will require a great deal of modification and adaptation. Keep in mind that these defenses are not the only options available for space system protection. These are just the defenses needed in a time critical situation when the timing of an attack is unknown or will occur too quickly for adequate response. These defenses will be used in conjunction with the entire gambit of space system defenses employed today.

Whipple bumpers are the most mature of the proposed defenses. It has already been developed to protect against similar hypervelocity threats to the ISS. The modifications needed to adapt to the role of kinetic ASAT defense is minimal. And, since it has been in development for over forty years and is being used today, the likelihood of producing a commercially viable product that will suit the needs of the space community is exceedingly high.

Nanotechnology represents the greatest gamble for eventually, much less in the near term, developing a useful protection capability. While there is great promise in nanotechnology and its use in satellite construction, the investigation of specific application of nanotechnology as a means of defending against directed energy ASATs is still in its infancy stage. "Much more work needs to be done to understand how the unique properties of nanomaterials can be

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[154] Tom Wilson, "Threats to United States Space Capabilities", Prepared for the Commission to Assess United States National Security Space Management and Organization, *Threat Annex to Report of the Commission to Assess United States National Security Space Management and Organization*. (Washington, DC: Congressional Press, 2001), 43.

harnessed to protect satellites against directed energy weapons threats. This will require the USAF to make this research thrust a priority and maintain it as such, which translates into a long-term financial commitment."[155]

That is certainly true for all research and development surrounding satellite self-defense. There are indications, however, that the Chinese ASAT test of 2007 in addition to China's increased interest in a wide variety of ASAT methods mixed with various interest among other adversary states to mitigate America's advantage in space provides the sort of wake up call necessary to begin increasing the funding to these research and development efforts. Now is the time to seriously consider and explore doing more to defend American satellite capability from disruptive and destructive threats.

The Downside of Chasing Additional Defense Measures

As previously identified, the chase for emerging technologies is always fraught with peril. Serious cost overruns can occur (similar to the F-22 and AGM-158 Joint Air to Surface Standoff Missile programs), technologies may never pan out to be viable or effective (like the jamming pod proposed for the B-52 electronic attack version), or the development may fade into obsolescence because of another discovery in the middle of research and development (like chromium audio tapes never taking root due to compact disk commercialization).[156] Unique to satellite defense, many of these technologies have to operate in the most inhospitable and forgiving of environments. Add the extra hurdle of trying to protect against a concentrated attack from earth-based resources not constrained in the same way the space object is. A lot of consecutive successes and miracles have to occur for the defense to work, and any single flaw spells disaster for the entire defensive measure. Overall the search for new space defense

[155] Huntington, "Improving Satellite Technology With Nanotechnology", 13.

[156] Michael Sirak, "Air Force Mulls Path Ahead for Protecting Satellites", *Defense Daily*, 25 September 2007(21-24): 21.

technologies is a very large gamble. But every other research endeavor is guilty of this. USAF Secretary Wynne identified that, “while protective measures are under review for future spacecraft, they may be too costly to justify in a war of attrition, and hard to integrate on some of the satellites.”[157] However, not attempting to develop emerging capabilities and search for exotic technologies would be a great failure. In this particular situation, with limited resources and an impending threat, a balance has to be struck between what is reasonably achievable (what has a high likelihood of success) in the near term against the likelihood of being attacked and the expected impact of a successful campaign against U.S. satellites. The riskier research must continue to occur, but for additional resources to be committed there must be a reasonable expectation of reward.

Unfortunately, predicting which resources, budget, and materials will lead to a successful program is difficult at best. Military acquisition, in general, has numerous failure and cost overruns associated with developing technologies. Space acquisition has been particularly problematic over the past decade. The Joint Task Force on Acquisition of National Security Space Programs identified several problems associated with the acquisition of space programs: “requirements definition and control issues; unhealthy cost bias in proposal evaluation; widespread lack of budget reserves required to implement high risk programs on schedule; and an overall underappreciation of the importance of appropriately staffed and trained system engineering staffs to manage the technologically demanding and unique aspects of space programs.”[158] The Joint Task Force highlighted four key issues and recommendations for fixing the space acquisitions process:

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[157] Ibid: 21.

[158] Joint Task Force on Acquisition of National Security Space Programs, *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs*, Defense Science Board and Air Force Scientific Advisory Board, Office of the Under Secretary of Defense For Acquisition, Technology, and Logistics: Washington D.C., May 2003: i.

> 1. Cost has replaced mission success as the primary driver in managing acquisition processes, resulting in excessive technical and schedule risk. We must reverse this trend and reestablish mission success as the overarching principle for program acquisition. It is difficult to overemphasize the positive impact leaders of the space acquisition process can achieve by adopting mission success as a core value.
>
> 2. The space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the acquisition process. These estimates lead to unrealistic budgets and unexecutable programs. We recommend, among other things, that the government budget space acquisition programs to a most probable (80/20) cost, with a 20–25 percent management reserve for development programs included within this cost.
>
> 3. *Government capabilities to lead and manage the acquisition process have seriously eroded.* On this count, we strongly recommend that the government address acquisition staffing, reporting integrity, systems engineering capabilities, and program manager authority. The report details our specific recommendations, many of which we believe require immediate attention.
>
> 4. *While the space industrial base is adequate to support current programs, long-term concerns exist.* A continuous flow of new programs—cautiously selected—is required to maintain a robust space industry. Without such a flow, we risk not only our workforce, but also critical national capabilities in the payload and sensor areas.[159]

Many of the unknowns associated with program development can be mitigated by utilizing previously proven technologies and utilizing them in unique ways (Whipple bumpers, for example.) However, even when using commercial off-the-shelf technologies, the testing necessary to prove a technology transfer will work can produce unexpected results and often does cause actual development costs to well exceed expectations. By that strict measure, it is hard to determine if chasing any one or all of the defensive technologies mentioned could be viewed as being successful. The real measure, however, is the cost associated with producing any given satellite defense technology vice equally effective defensive measures of some other kind. In turn, those measures are then balanced against the risk of having done nothing at all.

Lastly, one very popular argument against developing space defenses is the fear that it would precipitate a space arms race. Typically, this argument is more often associated with competing offensive capabilities; however, there is ample empirical evidence that improved

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[159] Ibid: iii-iv.

defenses can also cause an adversary to seek improved offensive weapon effectiveness. The original line of reasoning postulates that space assets are free from attack now because of the sanctuary they enjoy and because they do not represent a clear and present danger which an adversary feels compelled to directly challenge. Unfortunately, continued American reliance upon unchallenged space exploitation is slowly changing the equation. If the U.S. should develop more OCS capability (such as fielding a destructive ASAT or placing weapons in space) then other nations would feel compelled to develop an equal if not superior threat capability to balance the superiority of the U.S., which in turn creates a threat to the satellites that might not have existed in the first place.[160] The defensive theory is a twist of that original argument. It argues that creating an effective satellite defense to a demonstrated contemporary threat only encourages the adversary country to improve on the threat, thus leading to the arms race.

First, this line of thought assumes that the impetus causing the adversary to create space weapons in the first place can be abated or removed, and that only by making the adversary feel a greater or unreasonable risk does the arms race begin. While America has not placed weapons or even unassailable defenses in space yet, potential adversaries are feeling threatened by U.S. space dominance. It is unrealistic that the U.S. will forego the strategic and tactical advantages that space represents, or will willingly give up the dominance it enjoys today. It is exactly that dedication to space dominance that is making nations like China and North Korea turn to ASAT technology.[161] While U.S. weaponization of space in order to gain an offensive initiative can certainly be argued against, the only viable means to protect already threatened satellites is to improve defenses or suffer the consequences.

ASAT threats against U.S. satellites already exist and the adversary countries have demonstrated a desire to use them, if necessary. The U.S. cannot afford to do nothing about the

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[160] Spacy, “Does the United States Need Space-based Weapons?”, 4-5.

[161] Scott A. Henderson, “The Third Battle: Is the U.S. Ready to Wage the Next Conflict in Space?”, (Thesis, CADRE, Air University: Maxwell AFB, AL, March 2004), 22.

threat and hope that it will never be challenged in space dominance. Even reversing space policy today and negotiating a treaty to ban all ASAT weapons would not physically prevent an adversary country from secretly building a robust ASAT capability while the U.S. rests on its laurels. Arguing diplomatically that the adversary country was in violation of a signed treaty would provide little comfort as U.S. satellites continued to be disabled or destroyed. By fielding a defensive system that mitigates or negates the effectiveness of a threat, the adversary country will become less inclined to risk war with the U.S. by employing ASATs if they could not guarantee some reasonable expectation of success.

There is little evidence that specifically placing defenses onboard satellites will suddenly cause a space arms race to spiral out of control. Space systems are already protected through various means including threat of an air or surface attack, small maneuvers, configuration changes and others. These defensive measures exist today and a space arms race (if one exists at all) is proceeding at a relatively measured pace. Some can argue that U.S. DCS measures today are spurring the improvement of ASATs worldwide, but it is just as valid to point to inevitable strategic balancing that usually occurs against empires and hegemons throughout history as a stimulus for contemporary ASAT development.

Second, there is a simple economic balance that prevents a space arms race from spiraling out of control, especially when matching adversarial offensive threats against competing domestic defensive capability. Secretary of the Air Force, Michael Wynne, explained the economic math, "'I can't afford as a nation to just do an exchange ratio where they send up a $100 million [ASAT] missile and I send up a $1.5 billion satellite.'"[162] What the U.S. could afford, however, is to spend $45 million to neutralize the effect of the $100 million ASAT in protection of the $1.5 billion satellite. Most of the defenses proposed would cost less than or equal to the cost of a destructive ASAT. If they are effective and negate the usefulness of the

[162] Sirak, "Air Force Mulls Path Ahead for Protecting Satellites": 23.

threat ASAT, then the adversary has to increase spending to improve their ASAT. Typically that improvement cost is proportional to cost of the original system, in this case starting at $100 million. The same generally holds true for the defensive improvements. Therefore, the next spiral in the arms race would equate to a $200 million ASAT to attack a $1.5 billion satellite protected by a $100 million defensive system. And, much like the cold war, the U.S. would be in a position to outspend most any foreseeable adversary and neutralize the threat. That is based upon the assumption, of course, that defensive improvements could keep pace with offensive improvements technologically. Outpacing the potential adversary threat is exactly the goal of this proposal.

The arguments against additional defensive measures may spark interest initially but, once examined, have limited rationale that would warrant abandoning satellite self-defense development and employment. However, lacking good reasons against improving the defense of satellites does not imply that the measures should therefore be developed.

The Benefits of Chasing Additional Defensive Measures

The first and most obvious advantage of developing timely and responsive satellite defenses is that America's critical space capability would be preserved. Some of the technologies like increasing redundancy or whipple bumpers and nanotechnology can provide additional protection not only against ASATs but against a whole host of natural electromagnetic and projectile events that occur every day. Since nature can sometimes represent the biggest threat to the largest number of U.S. satellites, the additional protection ensures the availability of space exploitation when needed. The expeditionary nature of the American military depends greatly upon space for command and control, and modern military battlefields almost require precision weapons, many of which are also dependent upon space assets. Unfettered space support is necessary for the U.S. military to continue to function as it has over the past decade and predicted to do so in the future.

Many of the technologies presented as possible near-term candidates have been developed for terrestrial application. Just as the technology transfer can go from air assets to space assets, so can the applications of some of the technologies developed for protecting satellites. The miniaturization and autonomous processing that will inevitably precipitate from micro- and nano-satellite development can greatly aid unmanned aircraft development in addition to other air, sea, and ground platforms.[163] Aircraft could be made lighter and more capable. Ships could conserve space for additional supplies and ground vehicles could be made more reliable and have more room to carry additional equipment or supplies. Nanotechnology shielding could produce new means of concealing military vehicles from a vast array of sensors including from electronic sniffers.[164] Just as the space race of the 1960s produced a great deal of spin off technologies, not just for NASA, but for the U.S. military and for the civilian population as well. Similar spin offs can be reasonably expected from developing effective satellite ASAT defense.

Lastly, building an overwhelming defense may actually discourage adversary nations from pursuing offensive capabilities against the U.S.[165] "If a weapon is vulnerable, yet capable of dramatically affecting the outcome of a conflict, the state that possesses it has an even more powerful incentive to employ the weapon early on in a conflict"[166] Conversely, if a weapon is vulnerable and not capable of affecting the outcome of a conflict, which satellite self-defense

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[163] Barry Ray, "'Buckypaper': stronger than steel, harder than diamonds", Physorg.com, Florida State University, www.physorg.com/news7435.html (accessed 13 February 2008).

[164] Ibid.

[165] Everett C. Dolman, Peter Hays, Karl P. Mueller, "Toward a U.S. Grand Strategy in Space." *Washington Roundtable on Science and Public Policy*, (Washington D.C.: George C. Marshal Institute, 10 March 2006), 24.

[166] Brian C. Ruhm, "U.S. Air Force, Finding the Middle Ground: The U.S. Air Force, Space Weaponization, and Arms Control," (Thesis, Air Command and Staff College, Maxwell AFB, AL, April 2003), 30.

would achieve against current generation ASATS, then there would be little motivation to resort to ASATs.

It has been noted that often treaties designed to limit the research, development or production of an offensive space capability are simply a means to try to balance the overwhelming advantage of one nation over another. Much of the motivation for treaty proposals concerning banning ASATs and space weaponization are presented by nations who do not have a large stake in space, but would like to curb the disparate advantage enjoyed by the major space powers. Producing an overwhelming space defense may actually cause the Chinese and other space adversaries to negotiate and seriously abide by effective and lasting prohibitions against ASATs and space weapons.[167]

The Imperative to Start Now

On balance, the need to develop satellite self-defense capabilities is clear. Two adversarial nations have demonstrated a direct-ascent kinetic-kill ASAT capability. Several more have ground-based laser ASAT technology capable of dazzling, blinding, and even potentially destroying U.S. satellites. China has shown an inclination toward developing a wide array of ASAT technologies to disrupt U.S. space capability on a variety of fronts. China has also taken fairly provocative steps in their march toward testing their emerging ASAT programs:

> “amid concerns from military analysts wondering why Chinese spacecraft are in orbits that bring them within close proximity of key U.S. satellites, according to Air Force Times, February 2, 2007. The Chinese spacecraft do not appear to be conducting any particular mission and that has analysts worried. The satellites could be identifying the capabilities and mission of American space platforms, attempting to intercept their communications with ground-based receiver stations, or placed in position to explode or impact a U.S. satellite in times of war. “There is a menu of missions that could be performed that we are not yet clear about,” one unidentified

[167] Eric M. Javits, “A U.S. Perspective on Space,” in *Future Security in Space: Commercial, Military, and Arms Control Trade-Offs*, Ed. James Clay Moltz, (Center for Non-Proliferation Studies, University of Southampton, United Kingdom, May 2003), 52.

> source told the industry magazine. “These things aren’t being sent up there to be space rocks,” the source cautioned.”[168]

Unfortunately, as Secretary of the Air Force Wynne laments, “Currently all U.S. satellites reside ‘in peaceful mode’ on orbit, meaning they are not ‘well defended”[169] The U.S. has been able to rest comfortably with the knowledge that space represented a relative sanctuary. “The U.S. strategy for space control over the past decade has relied largely on non-destructive measures and the capability for terrestrial systems to disable ground based command and control stations or launch facilities. These measures have sufficed until now because of the relatively primitive state of potential U.S. adversaries’ systems and the paucity of their command and control links.”[170] That situation is quickly changing. Provocative acts have already been taken and unambiguous moves are being taken by adversaries today. The only prospect facing the U.S. is that more ASAT technology will proliferate to adversary nations as time marches on. The time to provide widespread defense to all critical U.S. security related satellites (both civil and military) is now.

The acquisition timelines associated with major program improvements range from approximately two years for Commercial Off-the-Shelf or Rapid Fielding Initiative programs to ten to fifteen years for major force programs like the F-22 or Future Combat Systems. If the U.S. is to respond to threats against U.S. space presence in the near future, efforts must be made now. Budgets must increase, priorities set, and resources allocated to reflect the renewed efforts to develop an adequate defense in time to protect against ASAT attacks.

Another reality is that program costs generally increase as time goes on. While any one single technology will become cheaper over time as it becomes more widely available and easier to manufacture, program development continues to become more expensive because of the pace

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[168] Howland, *China’s Anti-Satellite Program Alarming.*

[169] Sirak, “Air Force Mulls Path Ahead for Protecting Satellites”, 22.

[170] Ruhm, “U.S. Air Force, Finding the Middle Ground”, 29.

of technological advances that have to be included in order to remain relevant. Inflation also plays a role in making programs more costly over time, thusly using more national resources in order to achieve a similar effect. Waiting one or several years to decide if developing satellite defense is a high enough priority to warrant additional resources will cause more resources to have to be spent in the long run. All in all, the time to act is now.

Conclusion

America is highly reliant upon space exploitation and utilization for a wide array of national needs, ranging from national security, economic development, and even recreation. The U.S. derives a healthy amount of both hard and soft power from its dominance in space. It enables expeditionary force projection and global market integration, not to mention worldwide cultural interaction.

That dominance is being challenged today by nations that currently have an adversarial relationship with the U.S. Several countries are pursuing space anti-access technologies. A few key space-faring nations have looked toward a seemingly inevitable expansion of war into space and have decided to directly challenge America's presence in space. Ground based laser and direct ascent destructive ASATs are being developed by a handful of countries. Directed energy weapons are showing great promise. China has taken the most recent provocative moves against U.S. space assets in the past decade.

Currently, the U.S. does not have a robust satellite self-defense capability that is responsive enough to defend against a minimum to no warning attack against orbital platforms. That opens the U.S. up to a first strike scenario where an adversary can quickly neutralize America's space advantage and that could quickly make the opposing forces much more on par with each other. It would take months to years for the U.S. to regain the strategic advantage enjoyed during pre-hostilities. In many ways, the unprotected satellites are open to the same sort of first strike threat that America could leverage during the late 1940s when it solely possessed nuclear weapons. The U.S. would not be able to respond in kind to a "space Pearl Harbor" and would be dangerously hobbled for a seemingly interminable time. While there are defensive counterspace measures available today, they are not adequate to defend against the Pearl Harbor scenario.

Several emerging technologies are promising candidates for immediate or short term fielding. These defenses range from bodyguard microsats to passive protective coatings to active responsive shielding. Most of these are currently in a relatively low effort pace of development. An increase in resources and money could accelerate one or more of these programs to completion in a time frame that would be conducive to protecting the satellites against destructive attack in the near future. Once these technologies were employed, additional research and development can continue at a pace that is amenable to the budget and resource realities of the U.S. in the future and that is responsive to the changing security environment.

There are arguments both for and against chasing satellite self-defense technologies for immediate fielding. On balance the pros outweigh the cons and the development of the technologies could reap great benefits. Waiting longer would make forming an adequate defense after the fact or later down the road more costly. It may be too little too late if actions are not taken now.

Increased research and development should be undertaken to evaluate all the emerging technologies available that could be used for protection against destructive ASATs. This survey should be conducted as soon as possible and should be limited to only about six months. Upon completion of that survey, emergency funding should be shifted to improve the efforts of that given technology and future budget requests and resource allocations should follow the development of the program through fielding with a goal of initial operating capability within the next five years. Additional funding and resources should be allocated to longer term technologies that could be fielded within the next decade ensuring that America's space capabilities will remain viable for the foreseeable future. Not taking these recommendations to heart only increases the likelihood of suffering a devastating blow to American space exploitation and commensurate with that, a devastating blow to the American way of life.

APPENDIX

Glossary of Acronyms

AFRL – Air Force Research Laboratory

ANGELS – Autonomous Nanosatellite Guardian for Evaluating Local Space

ASAT – Anti-Satellite

CAUSNSSMO – Commission to Assess United States National Security Space Management and Organization

COPOUS - Committee on the Peaceful Uses of Outer Space

DARPA – Defense Advanced Research Project Agency

DCS – Defensive Counterspace

DIA – Defense Intelligence Agency

DoS – United States Department of State

GEO – Geosynchronous Earth Orbit

GPS – Global Positioning System

HAND – High Altitude Nuclear Detonation

ICBM – Intercontinental Ballistic Missile

ISR – Intelligence, Surveillance, Reconnaissance

ISS – International Space Station

LEO – Low Earth Orbit

MRBM – Medium Range Ballistic Missile

NASA – National Aeronautics and Space Administration

NGA – Non-Government Actor

NSP – National Space Policy

OCS – Offensive Counterspace

RAIDERS – Rapid Attack Identification Detection and Reporting System

SACC – Suppression of Adversary Counterspace Capabilities

SECDEF – Secretary of Defense

SLV – Space Launch Vehicle

SSA – Space Situational Awareness

TICS – Tiny, Independent, Coordinating Spacecraft

UNIDR – United Nations Institute of Disarmament Research

USAF – United States Air Force

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